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GEOGRAPHIC APPLICATIONS OF ERTS-I IMAGERY
TO LANDSCAPE CHANGE 162-III

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Final Report
NASA Contract NAS5-21726

Prepared for

Goddard Space Flight Center

National Aeronautics and Space Administration

Greenbelt, Maryland 20771

color
Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

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December 1973

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Final Report
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National Aeronautics and Space Administration

Dr. John B. Rehder
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Knoxville, Tennessee

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PART I

1.0 INTRODUCTION

Since 4 April 1972 the NASA-ERTS Geography Remote Sensing Project at the University of Tennessee has been conducting research investigations on the detection, monitoring, and delimitation of landscape change elements in Tennessee. Paramount to the investigation has been the testing and analysis of satellite imagery from the National Aeronautics and Space Administration's earth orbiting Earth Resources Technology Satellite (ERTS-I). Without the capabilities of ERTS in providing a view of the earth from a remote 560 mile altitude for synoptic investigations and the cyclic, sequential temporal parameters of the system on an 18-day cycle for change detection and monitoring, the study could not have been adequately accomplished.

1.1 OBJECTIVES

The primary objective of the proposed and ultimately accomplished research has been to analyze the ERTS-I data for the detection and monitoring of landscape change within the study area. Such landscape change elements as forest alterations, agricultural cycles of landuse, urban and suburban development, strip mining effects, and highway construction, have been of primary importance to the investigation and as such have formed the basis of the research effort.

The ultimate objective of the investigation, however, has been the identification, delimitation, and mapping of dynamic photomorphic

regions of landscape change. Specific objectives within this category include the monitoring and mapping of: (1) areas of forest alteration/newly cleared land, (2) areas which exhibit dynamic agricultural landscape change during the seasonal annual cycle, (3) patterns of constructive non-agricultural change such as roads, new settlement, new shopping center construction, and (4) specific sites of the destructive alteration of physical and cultural landscapes such as natural and man-made hazards of flood, fire, and erosion.

The objectives as stated here represent the nature of the proposed research objectives from the initial proposal of 14 April 1971¹ and the accomplished objectives and research results between 4 April 1972 and November 1973.

1.2 STUDY AREA

Because of the diversity of terrain features, landuse, and seasonal variation, eastern Tennessee and portions of western North Carolina were initially chosen to form the study area.

The investigation has focused on the East Tennessee Test Site, a 20,000 square mile region in which two smaller test sites are located (Figure 1). The Knoxville Test Site, an 11 x 21 mile area which encompasses the city of Knoxville and the western portion of west Knox County, has been investigated for landscape change associated with urban-suburban growth. A second test site of 17 x 10 miles on the Cumberland Plateau has been monitored for forest alterations and landform disturbances associated with the surface strip mining of coal.

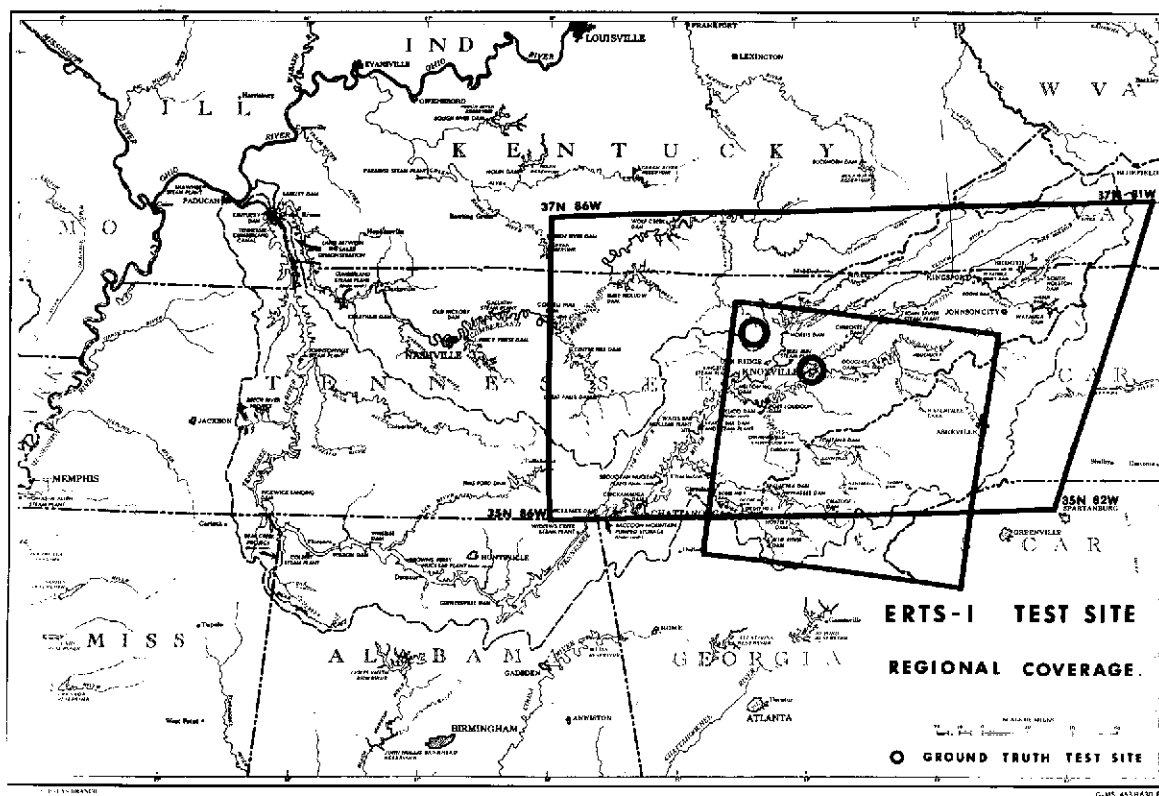


Figure 1. Map of the East Tennessee Test Site.

In addition to the primary test site in eastern Tennessee, other adjacent and larger areas have been analyzed for testing the change detection, synoptic, and mapping capabilities of the ERTS-I data. Sand Mountain, Alabama, south of Chattanooga, Tennessee, was analyzed for the detection of agricultural plowing practices. The Huntsville-Florence Alabama area was investigated for agricultural landscape change from ERTS-I imagery. In western Tennessee, the seasonal, short-lived phenomenon of spring (1973) flooding was analyzed for the Mississippi River floods between Cairo, Illinois and Memphis, Tennessee. Furthermore, statewide mapping efforts were established for mapping the forest cover of Tennessee and for mapping agricultural regions for the states of Tennessee and Kentucky.

1.3 STATEMENT OF WORK RESULTS BY PHASES

1.31 PHASE I - APRIL 4, 1972 to OCTOBER 1972

In the original ERTS-A proposal dated 14 April 1971, three phases of research were proposed. First, was a prelaunch period of collecting available aircraft imagery for data and map control and for comparative interpretations with the ERTS imagery.² This was accomplished by the acquisition of NASA RB-57 high altitude imagery flown on April 18, 1972. Although the high flight mission had been conducted for another investigation for the Tennessee Valley Authority, we were fortunate in obtaining copies of the imagery from the Johnson Space Center of Houston. Other data based information was generated through the use of low altitude (10,000') aircraft missions over the Knoxville Test Site.

Map resources were obtained from T.V.A. and the Tennessee State Highway Department during Phase I to further the controlled data base. Other preparations during Phase I included the acquisition of research interpretation equipment and office supplies and equipment for the project laboratory. Initially the lab was located in Buehler Hall of the Chemistry Department, however in October 1972, the project was moved to a three-room complex in South Stadium Hall under the football stadium.

1.32 PHASE II - NOVEMBER 1972 to JANUARY 16, 1973

The Phase II - "First Look" period of the project involved the initial analysis of imagery from ERTS-I following the successful launch of the satellite on 23 July 1972. Because of delays in receiving the first ERTS imagery, Phase II - "First Look" did not begin until mid-October, 1972. The first images received presented a disappointing view of a cloud and haze covered East Tennessee Test Site for August 22, 1972.

Like most investigators, we did not know what to expect to see from ERTS. We were initially expecting (1) greater clarity - of course not present in the initial stagnant air - haze and cloud covered scene, and (2) immediate interpretable results from a familiar landscape. The unfamiliar view of eastern Tennessee from an altitude of 560 miles was initially baffling. In one of our first looks at the imagery at the browse facility at Goddard Space Flight Center, we overran our test site two times while rolling out the imagery on the 70 mm film rolls. We found that the only possible recourse was to key in on the patterns of known T.V.A. lakes and streams best shown on band 7 of the M.S.S. (multi-spectral scanner). These initial first look blunders were not necessarily

the result of naivete, because we were qualified image interpreters who were more than casually familiar with the landscapes of the study area. I am convinced, however, that our mental maps of the area were initially at a scale of no greater than 1:250,000 and we required a period of approximately five minutes to adjust to the new synoptic perspective. Such first look experiences were felt by other investigators and are continually being experienced by professionals and laymen who see unfamiliar views of familiar areas for the first time from the synoptic perspective provided by ERTS.

Fortunately, Phase II was later marked by improved imagery with clearer, cloud-free views of the East Tennessee Test Site from 15 October 1972. The October imagery became the single most important and useable set of ERTS-I data until the reception of other useful sets of imagery dated 19 February, 14 April, 1 May, and 12 July, 1973.

Evaluations of spectral parameters of the imagery and data products from N.D.P.F. (NASA Data Processing Facility) were made during Phase II. Of the four bands from the M.S.S. (multi-spectral scanner), two bands were deemed to be infinitely better than the others. Band 5, in the .6 to .7 micron range, provided unquestionably the most useful spectral range for purposes of comparing and contrasting landscape signatures. The light-toned signatures of strip mines, highway construction, plowed fields, suburban developments, and shopping center sites were best identified on band 5 because of the contrast between light tones and dark vegetated tones as seen through the spectral window of band 5. Band 7 (.8 to 1.1 microns), though not as widely used as band 5, proved

to be significant for the detection and mapping of water surfaces. Not only permanent water bodies were best identified on this band, but also temporary water surfaces such as wet soils and forests following periods of heavy precipitation were easily detected (see Fig.29). The analysis of the Mississippi floods later in Phase III was totally dependent on the capabilities of band 7 in enhancing water surfaces within the near infrared portion of the electromagnetic spectrum.

Although band 4 (.5 to .6 microns) was essential to the production of color composite products, as an interpreting unit individually it was of far less use to the project. Band 6 (.7 to .8 microns) was much more similar to band 7 than band 4 was to band 5. Band 6, however, did not provide the same clarity and haze penetration that band 7 did and therefore 6 was of lesser value and use to the interpretive portions of our Phases II and III.

Other product evaluations performed during Phase II and later in Phase III were focused on the bulk vs. precision and the color vs. black and white parameters of the imagery. Throughout the two phases, bulk products far surpassed the precision products in terms of resolution, optical clarity, density, and even mapping capability. The precision products are definitely more accurate orthographically than the bulk products. However, from an interpretation standpoint in terms of object recognition, and identification the bulk products were far superior to the precision. One can argue the orthographic question and map accuracy standards in favor of the precision products, but if one does not identify a landscape element as easily on the precision product, then how can one map it? Favoring a compromise, our results show that unless

national map accuracy standards are totally essential to an investigation, the precision data products are not particularly needed. Our procedure has been to conduct all of our initial interpretation experiment and mapping experiments on the bulk imagery and then to compare this with selected portions of the precision imagery.

Experiments conducted during Phase II included resolution tests, comparisons with ERTS-I imagery with high altitude RB 57 imagery and low altitude aircraft imagery, and microdensitometric and computer map experiments. Tests for resolution were conducted on the October 15, 1972 imagery with specific application given to strip mine detection. Through the use of a 8X magnifying comparator, strip mines of 250' to 410' width could be detected on the ERTS imagery. Other resolution tests were applied to urban features. Unfortunately, the compact nature of urban core areas and their low contrast reflectance did not allow for adequate or even accurate measurements. The best features for resolution testing and object identification on M.S.S. band 5 were linear features in high contrast reflectance situations. Such features as highway construction sites which reflected bright, bare earth surfaces against dark vegetated backgrounds, could be measured at 300' - 420'. Likewise, strip mines which reflected from bright sandstone surfaces were strongly contrasted against dark coniferous forests. On M.S.S. band 7, the detection of water features produced remarkable results for measurements of stream widths, ponds, and small lakes. Furthermore, even water filled depressions within strip mines could be detected, identified, and measured to dimensions as small as 200 feet.

A comparative analysis of ERTS imagery and high altitude RB-57 imagery was made during Phase II. The RB-57 imagery flown from 60,000' on April 18, 1972 provided an extremely useful control data base at a scale of 1:120,000 for mapping landscape change parameters. (For further details of this procedure and results, see pages 59-65.) Of particular importance was the comparative analysis of strip mine scars on the Cumberland Plateau using ERTS-I and RB-57 imagery. Although specific internal details of the mines could only be determined from the RB-57 imagery, the ERTS data were important to the detection and identification of strip mine scars in general, and their boundaries and growth patterns specifically. Thus, internal characteristics within strip mines could not be clearly detected from ERTS but their boundaries could.

Because of the usefulness of this combination of imagery as a part of a multi-scale, multi-stage experiment of the investigation, such combinations of imagery were used in the operational portions of Phase III.

Comparative analyses were also made between ERTS-I, RB-57, and low altitude (7,000') imagery. Details of shopping centers, highway construction sites, and suburban development areas were clearly determined from the low altitude imagery for ground truth data.

Essentially the multistage, multiscale comparative experiments proved to be useful in the following ways: (1) the low altitude imagery was beneficial for ground truth data compared to ERTS; (2) the RB-57 imagery provided a mapping base and data control base as compared to ERTS; and (3) the ERTS imagery, as the paramount data product with temporal parameters and regionwide scales, was the primary platform to which the other forms and scales of imagery were compared.

Microdensitometric and computer analytical experiments were begun during Phase II and continued through Phase III. Using a Tech/Ops scandig 25 microdensitometer through the auspices of the Electrical Engineering Department to scan the ERTS imagery, we were initially able to digitize the ERTS-I image data into a computer map product. Although the map products were coarse in visual display, they could be altered in scale from the original 1:3,312,000 from the 70 mm film clips into computer maps of 1:33,000. Difficulties which plagued the experiments were centered on equipment breakdowns and the multi-step approach to digitizing pre-existing digital data. Instead of converting ERTS-I digital tape data directly into computer map output in what would be the simplest, most direct way, we were digitizing imagery which had been previously produced from a digital tape at NASA's Data Processing Facility at Goddard. Although we did not (at U.T.) reach successful conclusions with the experiment, we feel that it has the potential for reaching significant conclusions. Further details of this experiment are covered in the report on pages 46-52.

1.33 PHASE III - JANUARY 16, 1973 - NOVEMBER 23, 1973

Phase III research procedures were principally based on those established in Phase II. The multiscale-multistage procedure using imagery from ERTS, RB-57 high flights, low altitude missions, and ground truth fieldwork was of primary importance in the mapping of strip mining changes and urban landscape changes. The microdensity experiments were continued into Phase III but principally for experimental and not operational purposes.

A new procedure utilized in Phase III was based on experiments conducted on a VP-8 Image Analyzer, a microdensity and image color enhancer maintained by the Electrical Engineering Department under the direction of Dr. Robert Bodenheimer (see pages 53-56).

A negative photographic technique in image enhancement was begun early in Phase III and continued to be used effectively throughout the research period. Although details of the technique are covered on pages 30-40 in this report, the principle of the technique involved the production of negative photographic prints from color and black and white positive transparencies. Originally designed as an expedient photo printing process by this investigator in 1971, the negative print technique was applied to the ERTS imagery for image enhancement. With the negative print technique applied to band 5, cultural landscapes in terms of urban and suburban areas, shopping centers, highway construction sites, strip mines, and agricultural areas were enhanced in dark tones against a light background. On band 7 negative prints, water and topographic surfaces were enhanced in light tones and light shaded enhancements on dark surfaces displayed as tone reversals in the negative prints (see Figure 4).

The mapping of photomorphic regions and examples of landscape change occupied the majority of the Phase III activities. Three thematic mapping projects were accomplished: (1) a map of the forest cover in Tennessee mapped from ERTS-I imagery; (2) maps of agricultural landscape changes and agricultural regions in Tennessee and Kentucky based on plowed ground and cleared land signatures; (3) a two part series of maps on strip mining

changes; and (4) a map of urban-suburban growth changes in Knoxville, Tennessee.

In the following chapters, all techniques and results are covered systematically and the mapping of landscape changes are covered topically for the remainder of the report. Note in section 1.4 the results of the project as they are presented in the project calendar of research and presentations.

1.4 PROJECT CALENDAR OF RESEARCH AND PRESENTATIONS

April 14, 1971 - Submission of ERTS-A proposal to NASA. "Geographic Applications of ERTS-A Imagery."

April 4, 1972 - NASA-ERTS Geography Remote Sensing Project. Funding and research initiated.

May, June, 1972 - Acquisition of research and office equipment.

June 22, 1972 - Low Altitude Aircraft Overflight - Knoxville Test Site - 8000'

June 23, 1972 - Low Altitude Aircraft Overflight - Knoxville Test Site - 8000'

June 27, 1972 - Type I Report, Geographic Applications of ERTS-I Imagery. NASA #CR-127550. N.T.I.S. #E72-10008. National Technical Information Service, Springfield, Virginia, 4 pages.

July 6, 1972 - Low Altitude Aircraft Overflight - Knoxville Test Site - 8000'

August 14, 1972 - Low Altitude Aircraft Overflight - Knoxville Test Site - 8000'

August 14, 1972 - Type I Report, Geographic Applications of ERTS-I Imagery to Rural Landscape Change. NASA #CR-128097. NTIS #E72-10082. National Technical Information Service, Springfield, Virginia. 3 pages.

September 28-30, 1972 - Attendance at the ERTS Investigators Seminar - "Preliminary Findings from the Analysis of ERTS Observations" - Goddard Space Flight Center, Greenbelt, Maryland.

- October 3-7, 1972 - Attendance at the 8th Symposium on Remote Sensing of Environment. University of Michigan, Ann Arbor, Michigan.
- November 20, 1972 - Presentation of "Remote Sensing of Landscape Change: A Case for the Earth Resources Technology Program." 27th Annual Meeting of the Southeastern Division, Association of American Geographers, Miami, Florida.
- November 19-21, 1972 - Publication of "Remote Sensing of Landscape Change: A Case for the Earth Resources Technology Program," Papers in Methodological, Cultural, and Physical Geography, Vol. 2, pp. 89-91, Southeastern Division of the Association of American Geographers.
- November 27, 1972 - with James R. O'Malley, Publication of Regional Landscape Change: A Case for ERTS-I. NASA #CR-129227. NTIS #E72-10265. National Technical Information Service, Springfield, Virginia. 10 pages.
- December, 1972 - Type II Report. Geographic Applications of ERTS-A Imagery to Rural Landscape Change. NASA #CR-129668. NTIS #E72-10355. National Technical Information Service, Springfield, Virginia. 34 pages.
- December, 1972 - Abstract publication of "Geographic Applications of ERTS-I Imagery to Rural Landscape Change." NASA #CR-128371. NTIS #E72-10177. National Technical Information Service, Springfield, Virginia. 4 pages.
- December 22, 1972 - Abstract publication of "Geographic Applications of the Earth Resources Technology Satellite (ERTS-I) to Landscape Change." NASA #CR-129564, NTIS #E72-10315. National Technical Information Service, Springfield, Virginia. 2 pages.
- January, 1973 - Image enhancement techniques in negative printing established.
- January 1, 1973 - Publication of "Geographic Applications of ERTS-I Imagery to Rural Landscape Change 162-III," I.E.E.E. Transactions on Geoscience Electronics, Vol. GE-11, No. 1, page 26.
- January 15, 1973 - Submission of ERTS-B Proposal to NASA. "Geographic Applications of ERTS-B Imagery to Landscape Change."
- January 16, 1973 - Data Analysis Plan for Phase III Research Approved.
- January 30, 1973 - with James R. O'Malley, Technical data for NASA from Geographic Applications of ERTS-I Imagery to Rural Landscape Change in Eastern Tennessee. NASA #CR-130319, NTIS #E73-10040. National Technical Information Service, Springfield, Virginia. 23 pages.

- February, 1973 - Microdensitometric and computer analysis experiments.
- March 7, 1973 - Presentation of "Geographic Applications of ERTS-I Data to Landscape Change." At the Symposium on Significant Results Obtained from the Earth Resources Technology Satellite - I. NASA-Goddard Space Flight Center. Sheraton Hotel, New Carrollton, Maryland.
- March 5-9, 1973 - Publication of "Geographic Applications of ERTS-I Data to Landscape Change." Symposium on Significant Results Obtained from the Earth Resources Technology Satellite - I. Vol. I, Section B, pp. 955-963. NASA Special Publication #327. March 5-9, 1973.
- March 27, 1973 - with James R. O'Malley - Presentation of "Geographic Applications of ERTS-I Imagery to Rural Landscape Change in Eastern Tennessee," at the Second Annual Remote Sensing of Earth Resources Conference, University of Tennessee Space Institute, Tullahoma, Tennessee.
- March 27, 1973 - With James R. O'Malley - "Geographic Applications of ERTS-I Imagery to Rural Landscape Change in Eastern Tennessee." Remote Sensing of Earth Resources, Vol. II. F. Shahrokhi, Editor. Selected papers from the 2nd Annual Remote Sensing of Earth Resources Conference, University of Tennessee Space Institute, Tullahoma, Tennessee, pp. 1005-1011.
- April 13, 1973 - Low Altitude Overflight - Cumberland Plateau Test Site - 7000'.
- April 19, 1973 - Presentation of "Geographic Applications of ERTS-I Data to Landscape Change." In the Special Session - The Uses of ERTS Data in Geography. 69th Annual Meeting of the Association of American Geographers, Atlanta, Georgia.
- April 23, 1973 - Presentation of "The Earth Resources Technology Satellite (ERTS-I)," at the Chattanooga Engineers' Club, Chattanooga, Tennessee.
- April 28, 1973 - Presentation of "Geographic Applications of the Earth Resources Technology Satellite (ERTS-I) to Landscape Change," at the 1st Pan American Symposium on Remote Sensing, Panama City, Republic of Panama. To be published in the Proceedings of the 1st Pan American Symposium on Remote Sensing.
- May 4, 1973 - Low Altitude Aircraft Overflight - Mississippi River Flooding, Memphis, Tennessee.

- May 6, 1973 - Ground Truth Fieldwork - Great Smoky Mountains - to investigate phenological (seasonal) changes in hardwood forests.
- May 12, 1973 - Ground Truth Fieldwork - Knox, Union, Jefferson Counties - to examine zinc mine talings (observed as unidentified white surfaces on the ERTS imagery).
- May 12, 1973 - Ground Truth Fieldwork - Campbell County, Tennessee - to investigate strip mine activities.
- June 30, 1973 - Publication of Geographic Analysis of Landscape Change from ERTS-I Imagery. Type II Report. NASA #CR-132170, NTIS #E73-10661, National Technical Information Service, Springfield, Virginia.
- July 20, 1973 - Submitted with James T. Johnson, Map, "Strip Mining Landscape Change," to be published in a book by the NASA-Goddard Space Flight Center, Greenbelt, Maryland.
- July 31, 1973 - Publication of Applications of ERTS-I Data to Landscape Change in Eastern Tennessee. NASA #CR-133422, NTIS #E73-10843, National Technical Information Service, Springfield, Virginia.
- August, 1973 - Submitted with Earl J. Tullos. "Map of Forest Cover in Tennessee as Derived from ERTS-I Imagery." To be published in a book by NASA-Goddard Space Flight Center, Greenbelt, Maryland.
- August, 1973 - Ground truth fieldwork on highway construction sites in eastern Tennessee.
- October 13-14, 1973 - Ground truth fieldwork - Cumberland Plateau, Tennessee. To identify deforested areas in Bledsoe and Van Buren Counties.
- October 15-25, 1973 - Image enhancement procedures made operational on Image Analyzer VP-8 system.
- October 29, 1973 - Presentation of Significant Results of the NASA-ERTS Geography Remote Sensing Project to the Discipline Panel on Landuse. Building 8, Goddard Space Flight Center, Greenbelt, Maryland.
- Oct. 29 - Nov. 1, 1973 - Publication of "Applications of ERTS-I Data to Landscape Change in Eastern Tennessee," Proceedings of the Symposium on the Management and Utilization of Remote Sensing Data. Falls Church, Virginia: American Society of Photogrammetry, pages 598-609.

November 1, 1973 - Presentation of "Applications of ERTS-I Data to Landscape Change in Eastern Tennessee." Symposium on the Management and Utilization of Remote Sensing Data. U.S. Geological Survey and American Society of Photogrammetry. Sioux Falls, South Dakota.

November, 1973 - Image enhancement experiments with color negative printing.

November 24, 1973 - Phase III terminated.

December 1973 - June 1974 - Final Report.

PART II. TECHNIQUES DEVELOPMENT AND UTILIZATION

2.0 INTRODUCTION

The development of research techniques and their utilization formed a significant part of the efforts of the NASA-ERTS Geography Remote Sensing Project. The methods and procedures which were tested and used by the project personnel involved time-honored techniques such as ground truth observations and low altitude overflights as well as relatively unique techniques involving electronic and computer analysis of the imagery.

Because of the unique scale of data coming from ERTS, a multi-stage, multi-scale procedure was initiated for data collection and analysis. Proceeding from ERTS imagery to RB-57 high flight imagery, to low altitude aircraft overflights, to ground truth observations, techniques were developed and utilized to derive data from each of the lower stages to be compared with ERTS data.

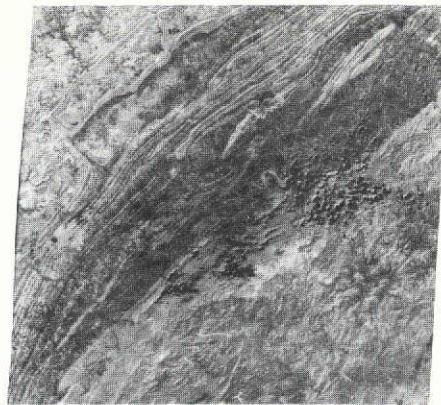
A second techniques development package was the photographic technique of producing black and white and color negative prints from positive products from ERTS. A third techniques procedure was the use of micro-density scanning equipment to convert point information into computer compatible products and computer maps.

Finally, an image analyzer system (VP-8) was used to convert ERTS imagery into color enhancements for real time analysis, density readouts, and for enhanced color reproduction.

2.1 MULTI SCALE - MULTI STAGE PROCEDURES OF DATA ACQUISITION AND INTERPRETATION

The multi-stage sampling procedure involved the generation and analysis of (1) surface ground truth imagery; (2) low altitude aircraft imagery from 7,000' to 10,000'; (3) high altitude RB-57 aircraft imagery from 60,000'; and (4) the ERTS-I imagery from an altitude of 560 miles. Two specific sites were investigated for the application of the procedure. One site, located on the Cumberland Plateau west of Knoxville, was monitored for strip mine landscape changes. The other site was centered on Knoxville and the primary suburban growth areas of West Knox County.

Before examining the details of our approach, several arrangements of the multi-scale approach need to be considered (Figure 2). One could have followed an inductive approach — leading from the specific to the general — to produce a quilt-like mosaic of parts which would have hopefully but laboriously led to a general conclusion. The inductive approach as stated for the project stages leads from ground truth investigations through the various aircraft scales to the synoptic ERTS-I view. This approach is far from being reasonable and is considered in this investigation only in regard to its philosophy. A second approach, the deductive approach, operates from the general to the specific line of reasoning. As applied to this investigation, the approach leads from the ERTS-I imagery down in a step-wise progression through the aircraft data and finally to specific ground samples. The deductive approach is far more useful in terms of scale, the choices of detail, and sampling procedure. Other investigators using this approach have found it philosophically and operationally successful.³ Finally the approach which this investigator utilized is based on a two-way procedure which begins near the center of the multi-scale matrix.



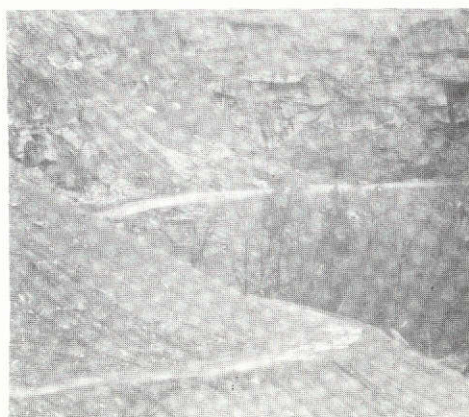
ERTS band 5
negative print
altitude: 560 miles



RB-57 High Flight
negative print
altitude: 60,000'



Low Altitude Aircraft
negative print
altitude: 7000'



Ground Truth
positive print
distance: 500'

Figure 2. Multi-stage, multi-scale imagery showing variations in scale and directions of procedure in analysis.

Beginning with the high altitude RB-57 imagery at 60,000' altitude and at a map scale of 1:120,000, we proceed up to the smaller map scale of ERTS (1:1 million) for comparison. Both platforms offer a regional synoptic view, and with ERTS data being used as the primary data source under investigation, it seems reasonable to compare it with the data scale nearest to it. From this first step, we proceed down to the larger scale data in the low altitude aircraft imagery which in reality is a form of ground truth data. The final step is to the genuine ground truth samples selected on the basis that information gathered from this stage could not have been obtained from any of the other stages.

For an understanding of the components of the multi-scale - multi-stage experiments, an examination of each of the remote sensing platforms, sensors, and analysis equipment is necessary. The following data sheets offer in a tabular form the significant elements of each stage of data collection, analysis, and cost benefits.

2.12 STAGE 1 - ERTS-I

1. Altitude - 560 miles
2. Imagery Scale - 1:998,136 to 1 million for 9 1/2"x 9 1/2" imagery
1:3,312,000 for 70 mm imagery
3. Image Area - 13,225 square miles
4. Linear distance per frame - 115 miles
5. Sensors: multispectral scanner (MSS) Return beam vidicon (RBV)*
6. Film/Product: Bulk and Precision Black and White 70 mm and 9 1/2" x 9 1/2" transparencies
Bulk and Precision Color Composites 70 mm and 9 1/2" x 9 1/2" transparencies

*Not operating

7. Film Media: Negative and Positive black and white transparencies
Color composites (Bands 4, 5, 7) transparencies
8. Filters:
9. Spectral bands: Band 4 - .5 to .6 microns
Band 5 - .6 to .7 microns
Band 6 - .7 to .8 microns
Band 7 - .8 to 1.1 microns
10. Test Area: Eastern Tennessee for complete coverage.
Tennessee, Kentucky, Northern Alabama, Northern Mississippi,
and western North Carolina for selected dates of coverage.
11. Data Collection Frequency: Once every 18 days between August 22, 1972,
and October 24, 1974.
12. Analysis Equipment: 8x Tube magnifiers, fine scale comparators,
Hamilton light tables/Scandig 25 micro-densitometer
and IBM 360-65 Computer/Image Analyzer VP-8 System/
Beseler and Omega Dark Room Enlargers and Map-O-Graph
vertical enlarging projector.
13. Economic Considerations (Cost Benefits) - Quick cyclic repetitive
coverage. Synoptic view. Large area coverage
available at lower cost. For imagery alone the cost
for complete coverage of Tennessee would be \$140 of
ERTS imagery compared to \$150,000 for high altitude
aircraft imagery. The synoptic view allows for quick
generalized landuse mapping of all of the level I
categories of Anderson's landuse, classification and
many of the level II categories.⁴ The map of agricultural

regions for Tennessee and Kentucky was prepared from ERTS imagery in a total time of 20 man hours (see Section 4). An estimated 30 man days would have been required if high altitude aircraft data had been used.

14. Operational Capability: Already the system provides enough initial data to begin operational landscape change detection and monitoring. For long term change detection and operational capability, the system needs only to continue under ERTS-I or be continued through successive ERTS-B, C, etc. Because of the excessive cloud cover over much of the earth, extensive periods of coverage are needed to obtain a series of clear observations for any particular study area. For example: the East Tennessee Test Site received 25 ERTS observations and of these only 9 can be considered of particular clarity, and usefulness to the problem of landscape change. Thus under these conditions, many orbits and observations are required to produce a minimal number of useful sets of data.

2.13 STAGE 2 - RB-57 HIGH ALTITUDE AIRCRAFT

1. Altitude - 60,000'
2. Image Scale - 1:120,000
3. Image Area - 289 square miles
4. Linear Distance per Frame - 17 miles
5. Sensors: Wild-Heerbrugg RC-8 6" Lens f/1
Zeiss RMK 12" Lens f/1

6. Film/Product: Kodak Ektagraphic EF Aerographic (Normal Color #SO-397
Kodak Aerochrome Infrared (Color Infrared) #2443
7. Film Media: 9 x 9 Normal Color and Color Infrared Transparencies
8. Filters: Haze Filter - for SO-397 film
Wratten 12 Filter - for 2443 film
9. Spectral Bands: Normal Color (SO-397) - .3 to .7 microns
Color Infrared (2443) - .4 to .9 microns
10. Test Area - Upper East Tennessee. From the Kentucky-Virginia border with Tennessee southward to 50 miles south of Knoxville. East-West coverage from Boone, North Carolina, to Crossville, Tennessee. North-South linear distance 80 miles by an East-West distance of 150 miles.
11. Data Collection Frequency: One overflight for this coverage on April 18, 1972. Note: Other RB-57 imagery for portions of this same area exist for 1 flight line between Knoxville and Chattanooga in May 1971 and coverage for western North Carolina centered on Asheville, North Carolina for June, 1969. Furthermore, in February and May, 1973, additional coverage was made by a U.S. Air Force U-2 mission over central Tennessee and southeastern Tennessee. We now have access to 20 frames of this coverage.
12. Analysis Equipment - 8X Tube Magnifiers, fine scale comparators, Hamilton light tables/Beseler and Omega dark room enlargers, Map-O-Graph Vertical Enlarging Projector.
13. Economic Considerations (Cost Benefits) - High altitude aircraft imagery has proven its value to remote sensing for more

than a decade. Until satellite imagery, high altitude imagery was the only data source for large regional coverage with a synoptic view from each image. The value of RB-57 imagery to this investigation should be obvious: as a data base, a map base, and source of controlled information. If we consider RB-57 overflights for a single project, the direct costs incurred are expensive — approximately \$35,000 to fly the East Tennessee mission. If the imagery had been purchased from the EROS Data Center, Sioux Falls, S.D. the costs would have been \$2,435. However, the April 18, 1972 mission was produced by NASA for a Tennessee Valley Authority and Association of American Geographers project. Copies of the imagery have since been obtained by this investigation, the Tennessee State Planning Office, various divisions within T.V.A., and slides of the imagery obtained by local planning agencies such as the East Tennessee Development District and others. The dispersal of data sources such as this highflight data is of a considerable cost benefit nature. A multitude of research groups now have imagery with which to research, work, and plan — imagery which would have been otherwise prohibitive in costs to obtain on an individual project basis. More effective opportunities for the dispersal of high flight data needs to be established in the future.

14. Operational Capability: RB-57 and U-2 aircraft have proven their capabilities in previous high altitude missions for other investigations. For purposes of this investigation on landscape change, however, the high altitude aircraft imagery is useful as a data control base but does not offer the repetitive, cyclic, temporal coverage which ERTS regularly provides. Furthermore the map scale and areal coverage from high flights are not as synoptically optimal as the coverage offered by ERTS. The high flight system works well for small regions in which landscape and landuse details are of the utmost importance for a single temporal slice. But for large areal coverage — statewide or regionwide such as for the southeastern United States — RB-57 or high flight coverage is sketchy at best, expensive, and even if available still requires extensive mosaicing to the detriment of scale, accuracy in generalization, and data manageability. In short, once a data base is established by high altitude imagery, no further overflights need to be justified as long as satellite overpasses and low altitude missions continue to be made available for updating the data for landscape change detection and monitoring.

2.14 STAGE 3 - LOW ALTITUDE AERO COMMANDER AIRCRAFT

1. Altitude - 7,000' to 10,000'
2. Image Scale - 1:26,751 to 1:38,216
3. Image Area: 8.4 square miles to 17.4 square miles

4. Linear Distance per Frame: .92 miles (4,904') to 1.32 miles (7,006')
5. Sensors: Two Hasselblad Cameras 80 mm lenses
6. Film/Product: Kodak Ektachrome MS Aerographic - #2448
Kodak Aerographic Infrared Film - #2443
7. Film Media: 70 mm color transparencies
8. Filters: Color Infrared (2443) Wratten #8 or #12
Ektachrome (2448) Haze/Daylight Filter
9. Spectral Bands: Ektachrome (2448) - .4 to .7 microns
Color Infrared (2443) - .4 to .9 microns
10. Test Areas: Test Site I: Knoxville, Tennessee and West Knox County
Test Site II: Cumberland Plateau - Campbell County, Tennessee
11. Data Collection Frequency: Test Site I - Knoxville - 3 missions - two
during the summer of 1972 and one in the
summer of 1973.
Test Site II - Plateau - 1 mission -
spring 1973.
12. Analysis Equipment: 8X Tube Magnifiers, Fine Scale Comparators,
Hamilton Light Tables/Beseler and Omega Darkroom Enlargers,
Map-O-Graph Vertical Enlarging Projector; Rollei 35mm -
70 mm Slide Projector.
13. Economic Considerations (Cost Benefits): The low altitude aircraft
missions were designed to produce low altitude, large
scale detailed information for use in comparison with
ERTS imagery. Their primary value has been for ground
truth information collection. Such missions have been
exceedingly useful in collecting data from inaccessible

areas such as on the Cumberland Plateau for strip mine monitoring. The cost of such missions may seem undesirably high with aircraft operational costs set at \$150 per hour. However, the amount of data received per hour is far more than can be obtained from the ground. Furthermore, the vertical map perspective provided by the aircraft overflight cannot be obtained at this scale in any other effective way.

14. Operational Capability: Low altitude missions are currently operational for ground truth data gathering services. They are fundamentally operational for "quick look" observations of individual, small research sites such as individual sites of highway constructions, strip mines, subdivisions, shopping centers. In this case for spot observations, the low altitude system is operational. But the system with its complex of 70 mm Hasselblad and 35 mm Nikon cameras is not operational for continuous coverage mapping. If the requirement is continuous coverage mapping for an area of 150 square miles or more, mapping cameras and higher altitudes are required such as through conventional aerial surveys mapping services or by high flight RB-57 or U-2 platforms.

2.15 STAGE 4 - GROUND OBSERVATIONS

1. Altitude (distance from subject to lens) - 100' to 500'
2. Image Scale - 1:710 to 1:3533
3. Image Area - 4,374 square feet to 83,421 square feet = .1 to 1.91 acres

4. Linear Distance per Frame - 81' to 403'
5. Sensors - 35 mm Nikon camera with 50 mm 1.4 fl lens
 35 mm Pentax camera with 55 mm 1.8 fl lens
 6 x 7 cm Mamiya Press camera with 100 mm 2.8 fl lens
6. Film/Product - Kodak Kodachrome II Color Transparencies
 Kodak Plus X Black and White
 Kodak Panatomic X Black and White
7. Film Media - 35 mm Black and White Prints/Color Transparencies
8. Filters - Ultraviolet and haze filters
9. Spectral Bands - Kodachrome = Color reversal film balanced for daylight.
 Panchromatic .3 to .7 microns.
 Plus X and Panatomic X = Panchromatic .3 to .7 microns.
10. Test Areas: Knoxville, Tennessee and West Knox County
 Cumberland Plateau - 7 counties
 Jefferson County, Tennessee
 Great Smoky Mountains (Sevier County)
11. Data Collection Frequency: As needed for ground truth comparisons with
 ERTS and other data sources - approximately 15 separate
 observations.
12. Analysis Equipment: Hamilton Light Tables/Beseler and Omega Dark Room
 Enlargers/ 35 mm Kodak Carousel Slide Projectors/ 35 mm -
 70 mm Rollei Slide Projector.
13. Economic Considerations (Cost Benefits) - Ground truth observations, if
 kept to a minimum — as few as are absolutely necessary,
 can be obtained at low cost and are exceedingly rewarding.
 Ground transportation at a cost of 8¢ per mile is inexpensive

to the point that even several thousand miles of ground truth travel can be accomplished at nominal costs.

Although per diem expenses should be considered, they too do not drastically increase the daily operation of ground truth investigations. Although the research benefits which can result from ground truth cannot be measured in monetary gains, without this stage of the investigation, many more questions would remain unanswered.

14. Operational Capability - Ground truth research needs no proof of its scientific value. In any multi-stage, multi-scale experiment, a necessary stage is one which contains the objects or elements which form the most basic and fundamental part of the study. In this investigation of landscape change, we are most interested in the detailed landscape features of strip mines, agricultural fields, highway construction sites, mine tailings, and shopping center and apartment construction sites. Granted, low altitude aircraft imagery when used for ground truth observations performs most ground truth tasks surprisingly well. However, to obtain the details of strip mining activities, plowed ground, and construction progress often requires an on the spot observation and field interview with local informants to complete the task of establishing accurate ground truth information.

2.20 PHOTOGRAPHIC PROCESSING TECHNIQUES

The necessity of producing paper photographic prints for general analysis and publication illustrations prompted the project to reexamine and later develop negative printing techniques with the ERTS imagery. The three product types examined in the following sections 2.21, 2.22, and 2.23 are comprised of black and white negative prints, black and white transparencies, and color negative prints. The significant result is that all were developed as enhanced image products for improved and more reliable image interpretations.

2.21 BLACK AND WHITE NEGATIVE PRINTING TECHNIQUES

In 1971, this investigator first experimented with the contact printing of color transparencies (9" x 9") onto positive black and white paper.⁵ The results were negative black and white prints. Since that time, negative printing has become a standard and expected procedure in our research and production with negative prints being obtained from all bands of ERTS and even from ERTS color composites, from RB-57 imagery and low altitude aircraft imagery.

The mechanics of printing directly from transparencies is not unique as nearly all photographic printing is obtained in this way. The primary difference in negative printing is that positive black and white or color transparencies are printed directly onto positive black and white or color paper with a negative print being the result. The darkroom procedure is the same for negative printing as it is for normal positive print processing. For enlargements, the positive transparency is placed in the negative carrier of the enlarger and then projected on to the positive

paper on the easel. For contact prints, the positive transparency is placed directly on top of the positive print paper with a heavy plate glass weighting the combination down onto the easel. Then the enlarger is turned on for the proper number of seconds for the exposure. For quick results, instead of exposing with the enlarger, one can turn on the overhead incandescent room lights for a short 1 to 3 second exposure and the results are often better than exposures from the enlarger.

Chemical processing of the negative print is the same as with conventional black and white processing with the use of a developing bath, stop bath, fix bath, hypo eliminator bath and wash and dry procedures.

In all cases of black and white negative printing it is recommended that a high contrast print paper such as Kodak Medalist F-4, F-5 or Kodabromide F-4, F-5 paper be used. The high contrast paper enhances contrasting information on the imagery and thus produces a photographic product different from a positive print or a negative transparency.

Utilization

The interpretative value of negatively printed imagery is the enhancement of light toned objects into dark ones. The imagery in figure 3 was obtained by contact printing MSS band 5 ERTS imagery onto Kodak Medalist F-4 black and white positive paper. Landscape features which in reality are high in reflectance and light in tone, appear on the negative print as dark tones. The lines and dots of deepest, darkest intensity are the features with the highest reflectance. Thus within areas of normally dark forest cover, the imprint of man-made features such as strip mines, road construction sites, urban clusters,



Figure 3. ERTS-I band 5 negative print of the East Tennessee Test Site. Dark tones are enhanced to illustrate cultural landscape features. 12 July, 1973. Id. no. 1354-15431-5.

Enhanced Image: Enhancement of cultural landscape features:
agricultural lands, highways, cities, and surface mines.

Image Identification Number: 1084-15431-5

Image Type: MSS band 5- printed through positive transparency

Altitude: 560 miles

Location: eastern Tennessee/western North Carolina

Date: October 15, 1972 10:43 am

Interpretation/Description: Negative print enhances cultural
landscape features by reproducing them in dark tones. Roads
appear as dark lines (Interstate 81 upper right), cities as
large dark masses (Knoxville left of center), broad agricul-
tural lands to the East, and strip mines as dark lines to the
West.

Technical Information

print paper: Kodak Medalist F-4

Enlarger: Beseler

Lens: Schneider 105mm

Aperture: f 4.5

Exposure Time: 5 seconds

Developer/Developing Time: Kodak Ektaflo #1

1 minute

Stop Bath: Kodak Ektaflo Stop Bath

Fixer: Kodak Rapid Fixer

and cleared fields are deeply etched as dark tones on the imagery. What had been a dominant dark forested surface in the original positive imagery, is now subdued to a light toned, almost imperceptible land cover on the negative print. This, of course, allows the features of more direct interest (i.e. strip mines, highways, suburban growth areas, etc.) to be enhanced and thus become more easily detected, identified, and mapped.

The simplification of the imagery from hundreds of shades and tones into only a few dark tones on the light toned surface simplify the interpretation of the image. However, not all imagery should be used with the black and white negative print technique. Imagery for which subtle differences between intervening shades of gray must be interpreted is not usually suited to the technique. The technique operates best in high contrast situations. For example, the better contrasts are exhibited by light toned cultural features on dark forested backgrounds such as may be found in the humid, eastern United States and in areas where dark toned irrigated farms appear on light colored desert surfaces such as the arid western United States.

By negatively printing MSS band 7 from ERTS we can produce two different but striking enhancements of physical landscape phenomena. Figure 4 illustrates an enhancement of hydrologic features in eastern Tennessee through the use of a negative print from band 7. Critical is the exposure time because the object of the enhancement is to reduce all shades of gray to two simple tones - black and white. An exposure of 30 seconds through a Schneider lens at an aperture of $f/4.5$ is sufficient to "burn" most of the gray and light toned signatures from the original imagery. In other terms, the process converts everything of light toned

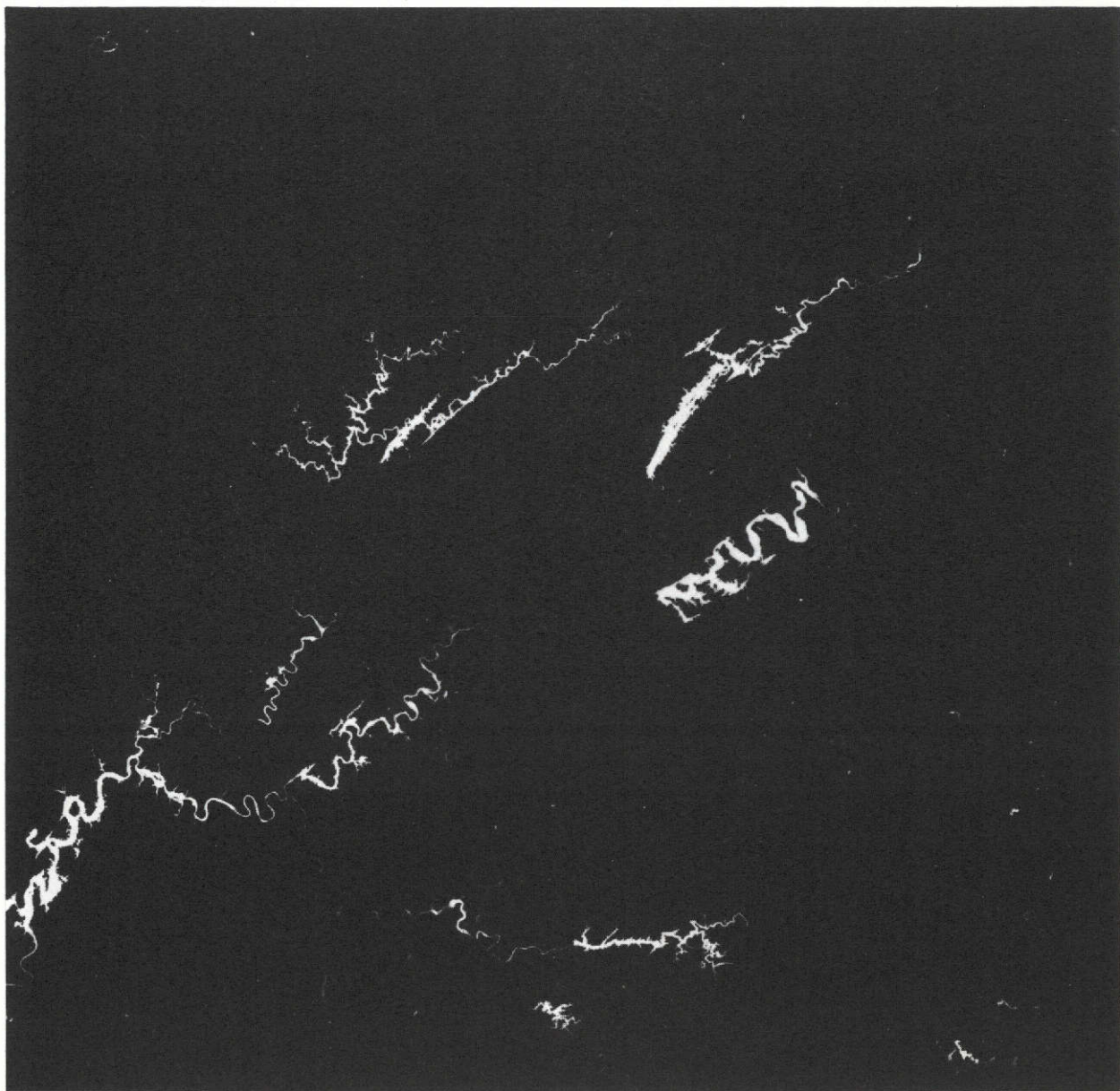


Figure 4. ERTS-I band 7 negative print of the East Tennessee Test Site. White tones are enhanced to illustrate hydrologic features. 12 July, 1973. Id.no. 1354-15431-7.

NASA-ERTS Geography Remote Sensing Project
Department of Geography
University of Tennessee
Knoxville, Tennessee 37916

Dr. John B. Rehder - P.I.

Enhanced Image: Enhancement of hydrologic features

Image Identification Number: 1084-15431-7

Image Type: MSS band 7- printed through positive transparency

Altitude: 560 miles

Location: eastern Tennessee

Date: October 15, 1972 10:43 am

Interpretation/Description: Streams and TVA reservoirs

appear in light tones with other physical features

suppressed. Note light toned enhancement of surface

moisture on the western slopes of the Great Smoky Mountains.

Technical Information

print paper: Kodak Medalist f-4

Enlarger: Beseler

Lens: Schneider 105mm

Aperture: f 4.5

Exposure Time: 30 seconds

Developer/Developing Time: Kodak Ektoflo #1

20 seconds

Stop Bath: Kodak Ektaflo Stop Bath

Fixer: Kodak Rapid Fixer

value into a dark, almost black background, thus leaving the objects which reflect as water signatures as white lines and dots on the negative print. It is important to understand that water features shown on a positive print or transparency of band 7 appear as deep, dark signatures whereas on the negative print, water features appear white.

Figure 5 illustrates the enhancements achieved by negatively printing band 7 with a normal exposure time. This lightens the background and reveals a topographic enhancement. In the original positive infrared transparency, the land surface was expressed in shades of gray with little or no differentiation between tonal patterns, i.e. a subtle and almost homogeneous background. However, on the negative print, the former gray surface is converted to a darker one with a highlighting effect applied to areas of surface roughness. Thus landforms with relatively pronounced slope characteristics are revealed appreciably in an enhanced light. The rugged mountain surfaces of the Great Smoky Mountains appear to the east and southeastern portions of the image and the roughened dissected sections of the Cumberland Plateau appear to the west and northwest. Within the Ridge and Valley area of East Tennessee, at the center of the image and extending diagonally northeast to southwest, one can see even smaller landforms such as low ridges and knobs enhanced on the image.

2.22 NEGATIVE TRANSPARENCY PRODUCTS

Kodalith, a transparent, negative-like material, is another medium upon which we have processed ERTS imagery. Using a positive band 5 transparency, we have produced a negative transparency from a positive transparency. One would suspect that such a procedure would be needless

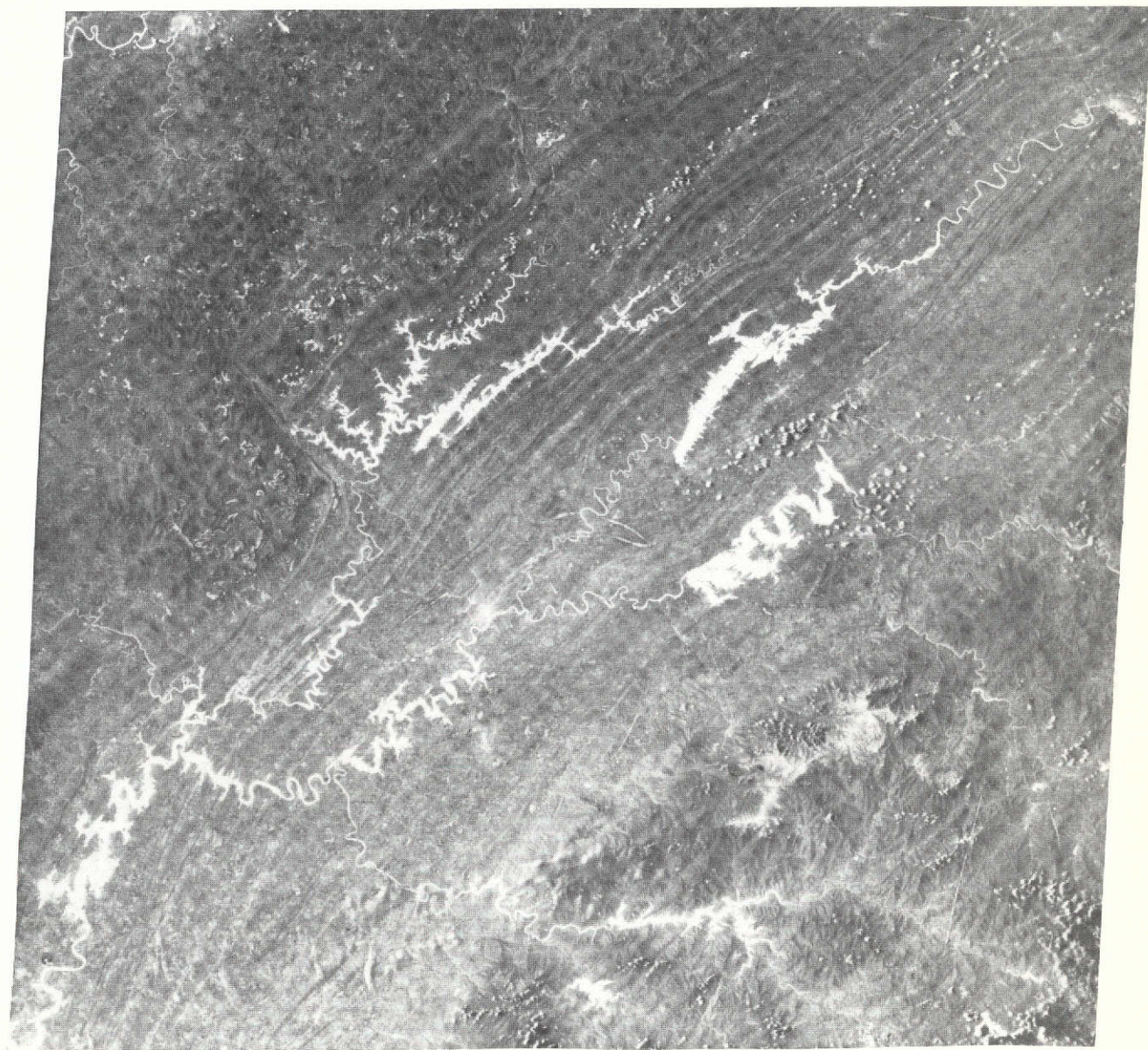


Figure 5. ERTS-I band 7 negative print of the East Tennessee Test Site. Note the combined enhancements of hydrologic features and landforms. 12 July, 1973. Id.no. 1354-15431-7.

NASA-ERTS Geography Remote Sensing Project
Department of Geography
University of Tennessee
Knoxville, Tennessee 37916

Dr. John B. Rehder - P.I.

Enhanced Image: Enhancement of topographic and hydrologic features.

Image Identification Number: 1084-15431-7

Altitude: 560 miles

Location: eastern Tennessee/western North Carolina

Date: October 15, 1972 10:43 am

Interpretation/Description: Negative print enhances light toned hydrologic features-reservoirs, streams, and surface moisture. Topographic grain, surface roughness, slope angles and lineated ridges are sharply enhanced.

Technical Information
print paper: Kodak Medalist F-4

Enlarger: Beseler

Lens: Schneider 105mm

Aperture: F 8

Exposure Time: 10 seconds

Developer/Developing Time: Kodak Ektaflo #1

1.5 minutes

Stop Bath: Kodak Ektaflo Stop Bath

Fixer: Kodak Rapid Fixer

with the availability of 70 mm negative transparencies directly from N.D.P.F. (Nasa Data Processing Facility - User Services). The values of producing our own negative products are threefold: (1) Negative transparencies can be made in larger formats of 5" x 7" to 8" x 10", (2) negative transparencies made with Kodalith are high in tonal contrast, and (3) Kodalith transparencies can be produced in either negative or positive transparency products and then projected onto viewing screens or onto positive print paper in the darkroom for print products.

Utilization. The transparent nature of Kodalith is its primary significance to the project. Not only can it be projected for public viewing, it can also be edited by darkening or painting out undesired objects or tonal patterns. For example, in the production of a "forest-only" thematic map, we produced a Kodalith negative transparency from a positive band 5 transparency and then painted out the superfluous object signatures such as some of the cloud cover and water features. The result was the forest cover example in Figure 6.

Kodalith is especially useful in producing multiples of negative transparencies for different observation dates. By sandwiching various combinations of transparencies from different observation dates, it is possible to determine selected landscape changes which have occurred between the different dates.

2.23 COLOR NEGATIVE PRINTING

The production of color negative prints from color transparencies has been one of the more recent accomplishments of the project. As of October, 1973 we have been processing ERTS-I bulk color composites into color negative prints in a variety of enlargements and color combinations.

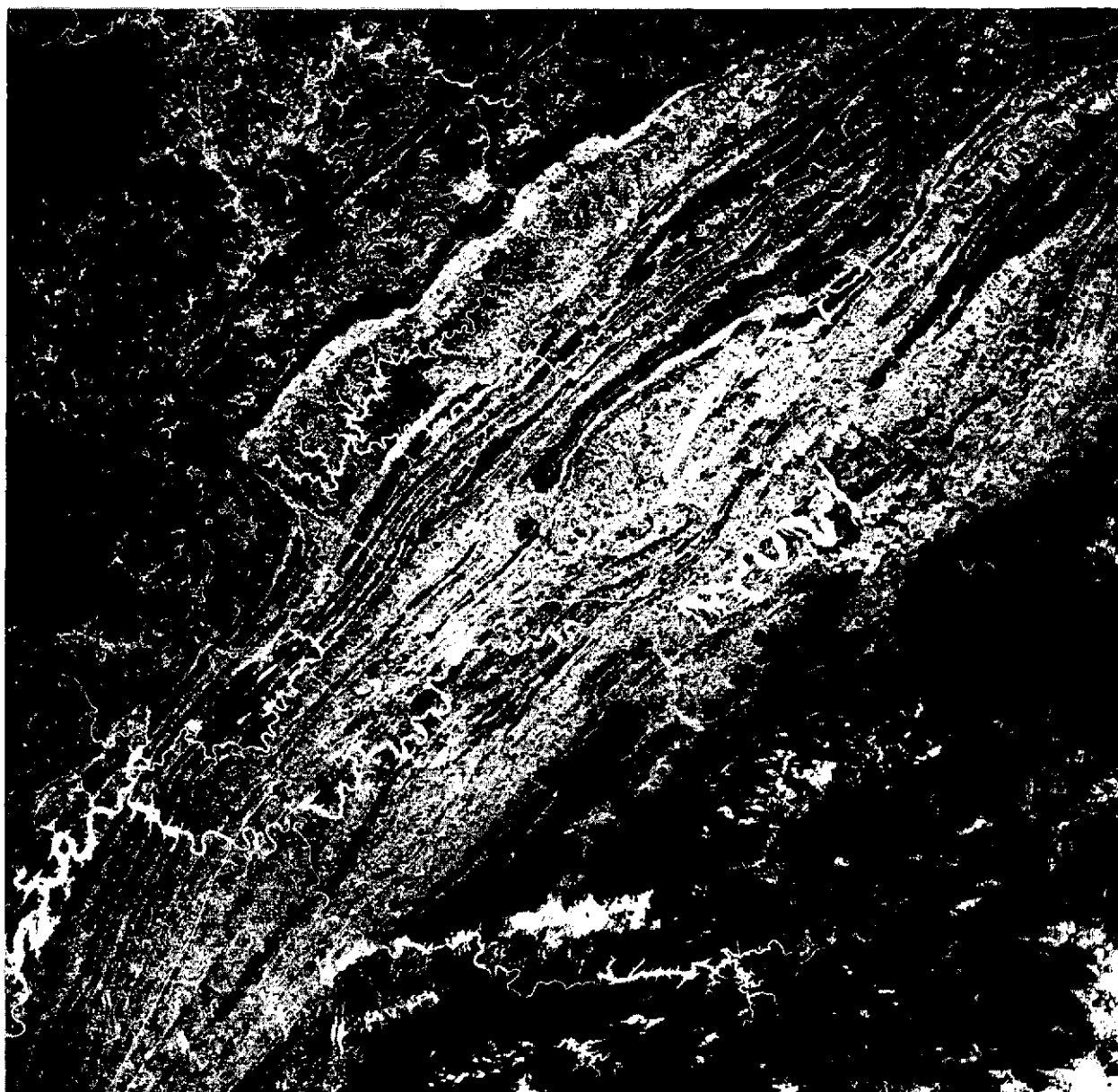


Figure 6. Positive print from a Kodalith transparency (negative) which was generated from an original positive ERTS-I band 5 transparency. All black tones represent forest cover. East Tennessee Test Site. 12 July, 1973. Id.no. 1354-15431-5.

Enlargements from 2X to 4X or up to 1:250,000 map scale have been made and color combinations have been produced in 5 combinations with the most useful being the one shown in Figure 7.

The technique of negative color printing requires basic color processing equipment and fundamentals which are not wholly different from those in black and white processing. Philosophically and technically the negative print technique is the same for color and black and white. To produce color negative prints on a small scale the photo technician minimally requires beyond a basic black and white darkroom setup the following items: A Kodak Ektaprint #3 Color Processing Kit, Ektacolor RC 37 paper, accurate color processing thermometers, and controlled water temperatures to within 1 degree Fahrenheit.

The contact printing procedure is much the same as for black and white. The bulk color positive is placed over the RC 37 color print paper and held in place by a heavy plate glass cover. Exposure is accomplished by a darkroom enlarger equipped either with a color head or a set of color compensating filters. The color filtration is set to the following arrangement: cyan = 0, magenta = 50, yellow = 50. Exposure for the print in figure 7 was f/11 at 13 seconds. Processing of the print is done in four stages: developing 3.5 minutes, bleach/fixer = 1.5 minutes, wash = 2 minutes, stabilizer = 1 minute. Following this, the prints are air dried for approximately 15 to 20 minutes after which the printing and processing procedure is completed.

Utilization. Paramount to color negative printing is the use of color compensating filters in the photographic enlarger to produce appropriate colors for land cover signatures. The result is the color

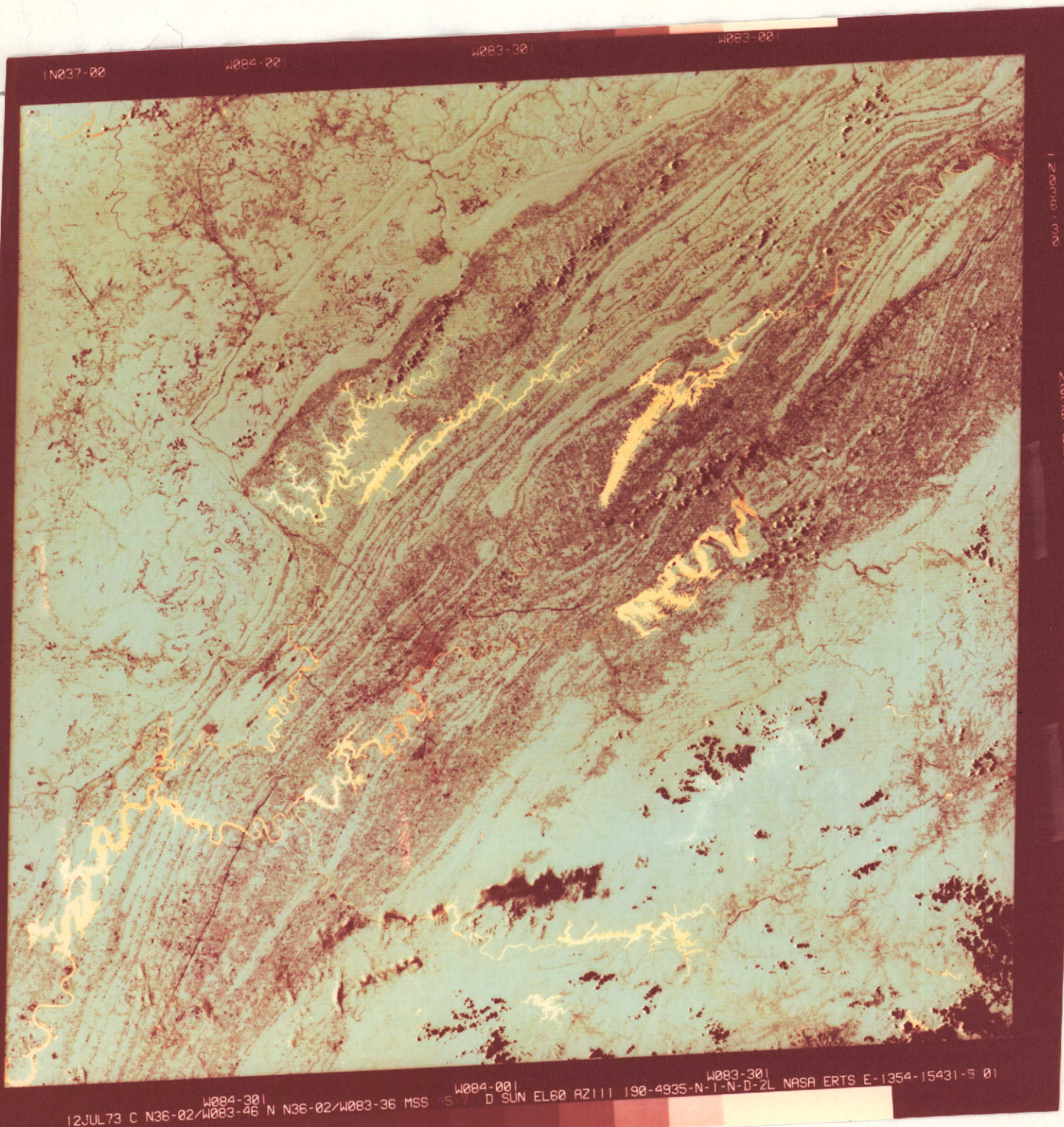


Figure 7. Negative color print generated from an ERTS-I bulk color composite. East Tennessee Test Site. 12 July, 1973. Id.no. 1354-15431.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

print in Figure 7 with green colors and hues representing forest cover, yellow or tan representing water features, red for urban areas and major highways, and maroon representing cleared land and agricultural land combinations. Although not completely "natural in color," this color product in part realistically associates green hues with forest cover and a muddy yellow color to the water features. Certainly not all of the hydrologic features in East Tennessee are actually a silty tan but the rendition is acceptable for some. The high contrast between the green and red hues is important to the separation of physical and cultural landscapes. The red and maroon color assignments accentuate the cultural landscape features of urban-high density settlement, highways, cleared (deforested) lands, and agricultural lands. When matched with the green forest signature, the red and maroon color assignments become sharply contrasted and are thus more easily discerned and mapped.

2.24 UTILIZATION SUMMARY OF ENHANCED PHOTOGRAPHIC PRODUCTS

To sum up the utilization of the three photographically enhanced image products — negative prints, negative transparencies, and color negative prints — it is best to compare their uses in landuse mapping. In reference to Figure 8 below, under category 1, note that the high density urban category can be detected and mapped with the use of Kodalith and color negative enhancements. Although with negative black and white prints we can detect an urban category, it is a broad based one of urban and built up land with an absence of details in higher density settlement. Note, however, that with the color negative print the differences between high density and medium density urban can be determined.

ENHANCED ERTS PRODUCTS AND LAND USES THAT CAN BE
CONSISTENTLY IDENTIFIED WITH THEM

<u>PRODUCT</u>	<u>NEGATIVE PRINTS</u>	<u>KODALITH NEGATIVE TRANSPARENCY</u>	<u>COLOR NEGATIVE PRINTS</u>
(Original)	(Bulk B & W Bands 5, 7)	(Bulk B & W Bands 5, 7)	(Bulk Color Composite)
<u>LAND USE CLASSIFICATION</u>	1. URBAN & BUILT UP LAND	1. HIGH DENSITY URBAN	1. HIGH DENSITY URBAN
	2. AGRICULTURAL LAND	2. AGRICULTURAL & CLEARED LANDS	2. MEDIUM DENSITY URBAN
	3. FOREST LAND	3. FOREST LAND	3. AGRICULTURAL & CLEARED LANDS
	4. WATER	4. WATER	4. FOREST LAND
	5. BARREN LAND		5. WATER

Figure 8

All three enhanced products allow for the detection and mapping of the next three categories: Agricultural and Cleared Lands, Forest Land, and Water. Each product is sufficiently different to produce different degrees of detectability. Agricultural and cleared lands are best detected and mapped from color negative prints. Forest land is best mapped from Kodalith. Water surfaces are best detected and mapped on ERTS band 7 negative or positive products. The final landuse category — barren land — is identified and mapped most effectively from negative print products.

The information in Figure 9 combines all photographic techniques and describes two levels of landuse classification obtainable from enhanced ERTS imagery and supplementary sources. Under the unaided interpretation level, all landuse categories from urban and built up through agricultural, forest, water, and barren land can be detected and mapped from the collective group of enhanced ERTS imagery techniques.

Under the supplemented interpretation level, all detailed categories can be detected on ERTS imagery but for those categories marked with an asterisk (*), additional stages of aircraft imagery are required for a positive identification of the category. Those categories which are unmarked can be clearly detected, identified, and mapped from the photographically enhanced ERTS imagery.

2.30 MICRODENSITOMETER AND COMPUTER TECHNIQUES

Through the services of Dr. Robert Bodenheimer in the Electrical Engineering Department at the University of Tennessee, image processing from microdensitometer and computer techniques have been performed for the project. As a service and experimental project, Bodenheimer's Image Processing Facility is designed to produce enhanced image products for

LAND USE CLASSIFICATION SCHEME UTILIZING ALL
PHOTOGRAPHIC TECHNIQUES, PRODUCTS AND DATES

UNAIDED INTERPRETATION

URBAN AND BUILT UP LAND

AGRICULTURAL LAND

FOREST LAND

WATER

BARREN LAND

SUPPLEMENTED* INTERPRETATION

1. HIGH DENSITY URBAN
 2. MEDIUM DENSITY URBAN
 - *3. RESIDENTIAL
 4. TRANSPORTATION
 5. MIXED
-
1. CROPLAND
 - *2. PASTURELAND
-
1. EVERGREEN
 2. DECIDUOUS
-
1. STREAMS
 2. RESERVOIRS
 3. LAKES
-
1. STRIP MINES
 2. TRANSITIONAL

*Requires aircraft imagery for
positive identification.

Figure 9

the other ERTS investigators on campus (Figure 10). The basic capabilities of the Image Processing Facility which have been utilized by this project are as follows:

A. Computer Generated Data Printouts

1. Symbolic
2. Pictorial Graytone
3. Histogram Generation
4. Digital Filtering

B. Imagery Enhancement Techniques

1. Spectral Gradients
2. Clustering
3. Filtering
4. Color Additive Enhancement
5. CRT Display
6. X-Y-Z Display

Primary equipment utilized by the facility include: a Tech/Ops Scandig microdensitometer Model 25, a Kennedy Model 3110 9-track digital tape recorder, and the University of Tennessee Computer Center's IBM Computer System 360/65. The microdensitometer has a scanning aperture of 25, 50, and 100 microns and can measure densities over 256 increments.

For our purpose a filtration of the densities was required to provide adequate contrast parameters in the analysis of ERTS imagery. Figure 11 represents a computer generated printout of densities from ERTS imagery coverage of a strip mine area on the Cumberland Plateau. Because of the detailed scan by the microdensitometer the map scale has been enlarged from 1:3,300,000 on the originally 70 mm ERTS image to 1:33,000 on the computer map.

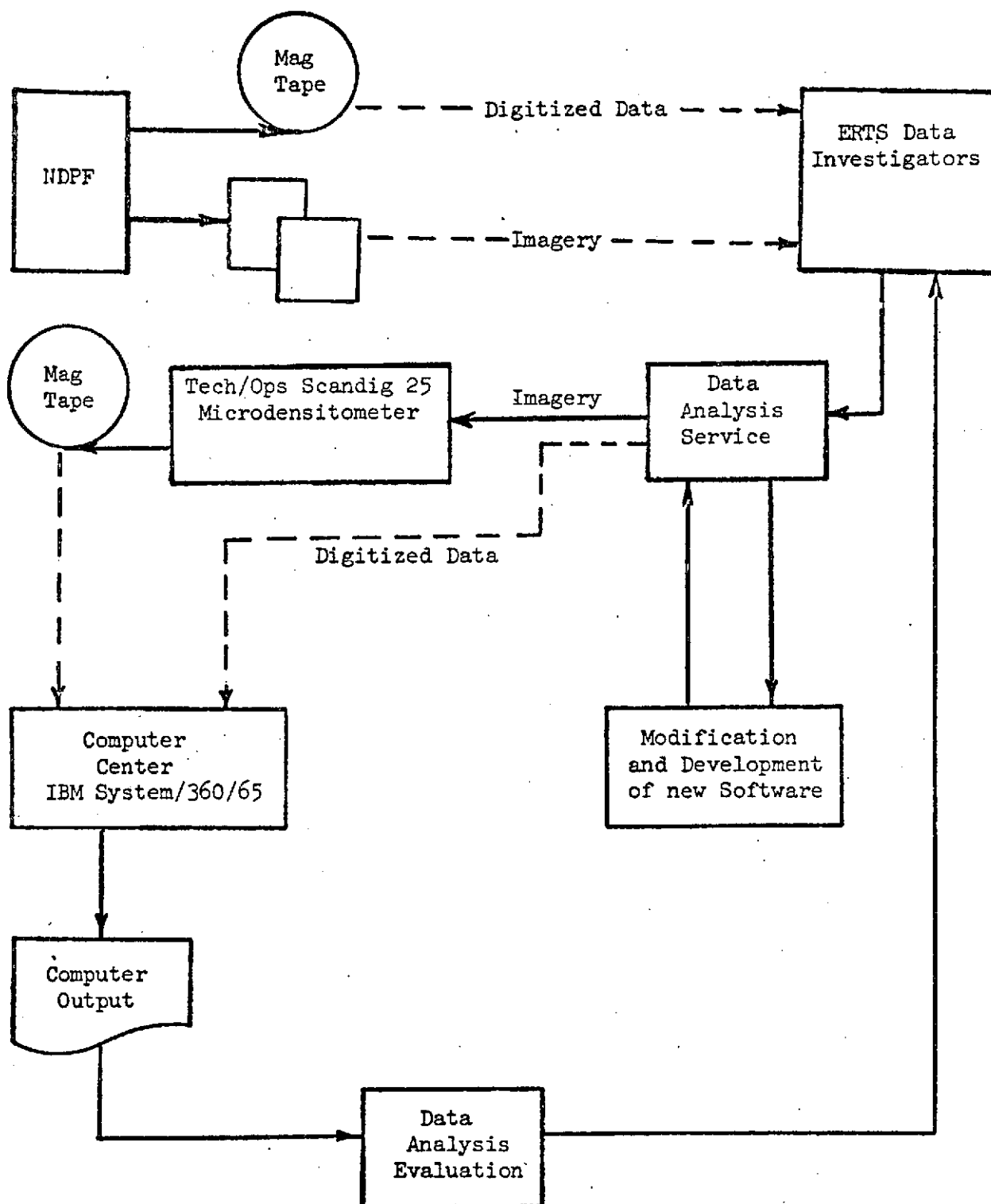


Figure 10. Flow diagram showing the handling and processing of data.

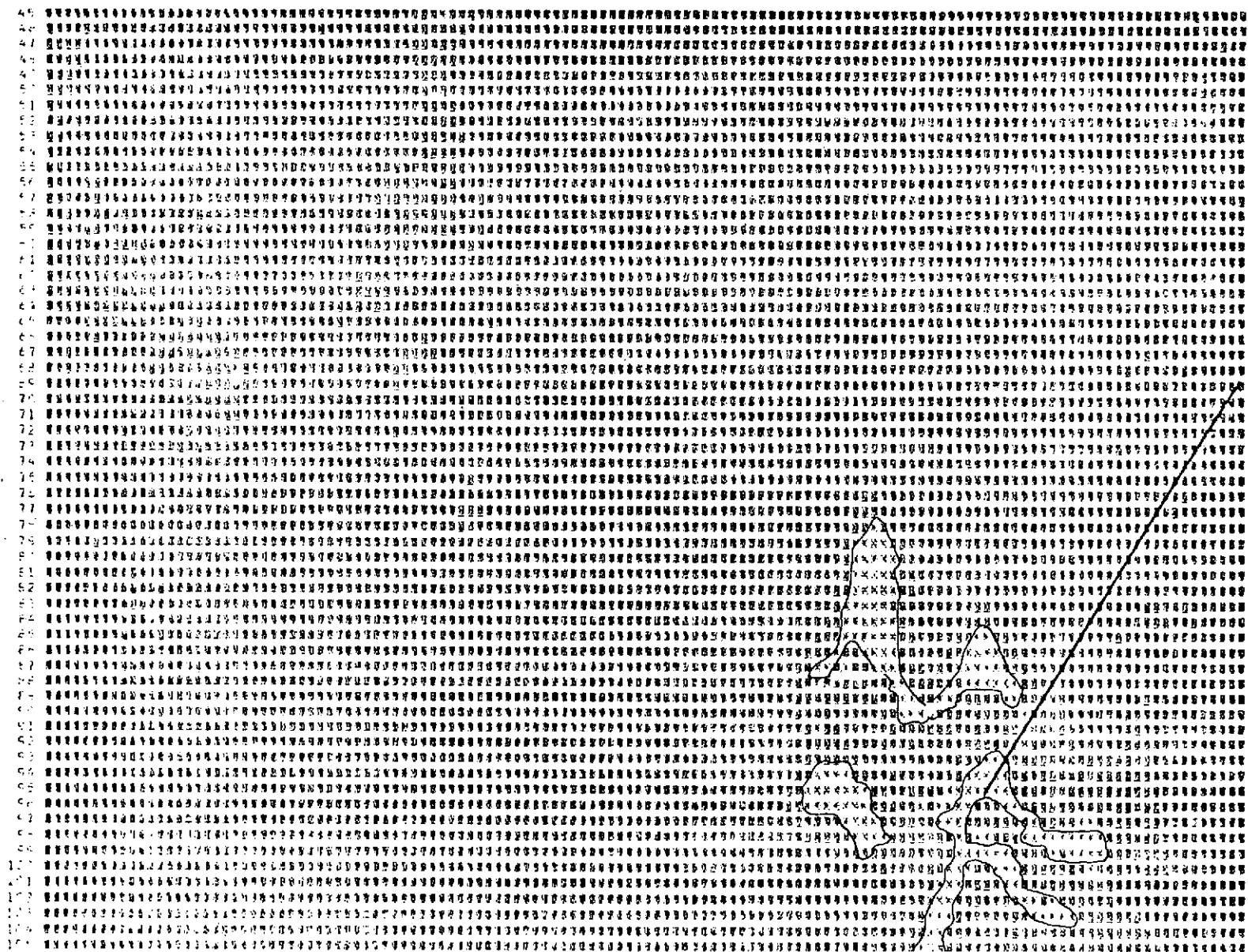


Figure 11. Microdensity scan of a computer map printout illustrating a strip mine configuration on the Cumberland Plateau Test Site. Derived from ERTS-I band 5 positive black and white imagery. 15 October 1972. Id.no. 1084-15431-5.

Utilization. The utilization of the microdensitometric and computer techniques has not been to the degree that we had originally expected. Delays in receipt of the initial ERTS imagery, mechanical breakdowns in the microdensitometer, and the delays in acquiring computer compatible programs and tapes for interfacing directly from ERTS tapes to computer printouts have all led to a minimal utilization of the system.

Despite these problems, an experiment with the microdensitometer and computer was conducted to analyze ERTS Band 5 imagery for strip mine changes. The experiment involved the microdensity scanning of the imagery for strip mines which appear as light tones against a dark forested background. The gray tone densities were then digitized and computer processed into a computer map and histogram. The object was to perform the procedure on ERTS imagery from two or more different dates. By comparing the machine analyzed data from the two dates, we attempted to determine if the number of light tones indicating strip mines had increased at the expense of dark tones for the same area. Unfortunately, extraneous signatures from clouds and light colored roads in the area resulted in the inverse from the expected. The two histograms in figure 12 represent the frequency distribution of the gray tones for the two observed dates of imagery. The August image was expected to appear with a fewer number of light tones (representing strip mines) than the October image. However, the opposite occurred because cloud cover led to a presentation of more light tones for August than for October.

I am convinced that given time and two or more cloud free images, such an experiment could reach a satisfactory conclusion. In concept, the experiment is justified and could and should be continued in the future.

AUGUST 1972

OCTOBER 1972

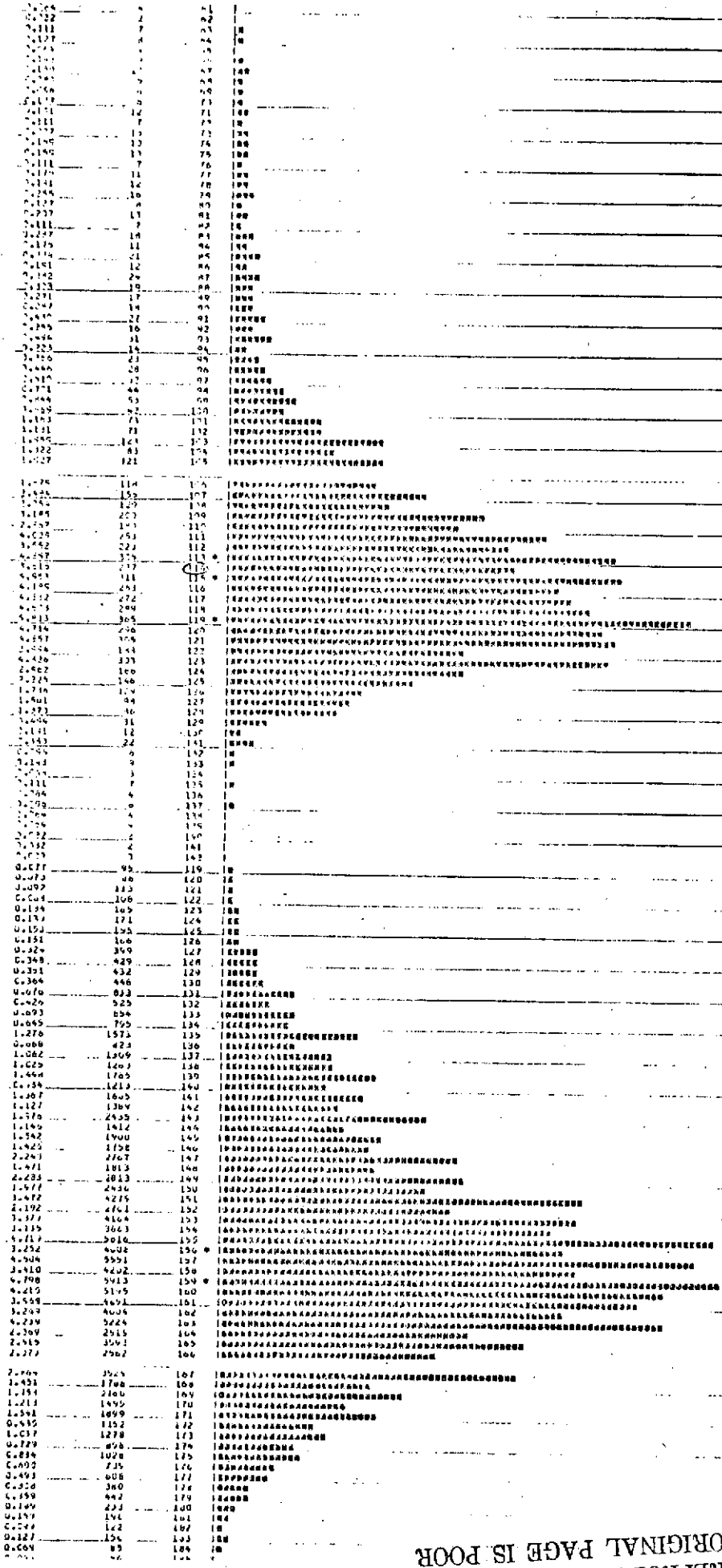


Figure 12. Histograms of gray tone densities of strip mines at the Cumberland Plateau Test Site. ERTS-I band 5 positive imagery. 22 August 1972 Id.no. 1030-15430-5. and 15 October 1972 Id. no. 1084-15431-5.

2.40 ELECTRONIC IMAGE ANALYSIS - VP-8 IMAGE ANALYZER

Also within the Image Processing Facility and under the direction of Dr. Bodenheimer is the VP-8 Image Analyzer System. Designed as a color additive viewer through microdensitometric and electronic manipulation, the system has been of greater success with our project even though we have only operated it during the remaining two months of the project.

The components of the VP-8 system include: a CCTV Input camera, the VP-8 analyzer, a black and white television monitor, a color television monitor, and a Hewlett-Packard X-Y-Z three dimensional monitor (Figure 13). Functionally, the system incorporates use of the CCTV camera to "photograph" a backlit ERTS transparency. The picture is then transmitted via cable to the VP-8 where the signal is measured densitometrically and for each density color coded. From the VP-8, the image is displayed either in black and white on the monochrome television display or in color on the color television display. Also from the VP-8, the image can be displayed on the X-Y-Z monitor where three dimensional presentations of the image can be made. The three dimensional image can also be rotated ± 180 degrees and inclined to 90 degrees to permit different viewing angles. Single scan line profiles of densities for any given horizontal cross section can also be displayed.

Within the VP-8 unit itself, is a digital readout display which can produce a density readout for any given coordinant on the viewing screen.

Utilization. The primary function of the VP-8 system for our project has been the capability of density level slicing and color enhancing. With level slicing, a display of from 1 to 8 colors can be achieved with each level color coded. For example, forest cover being a dark toned

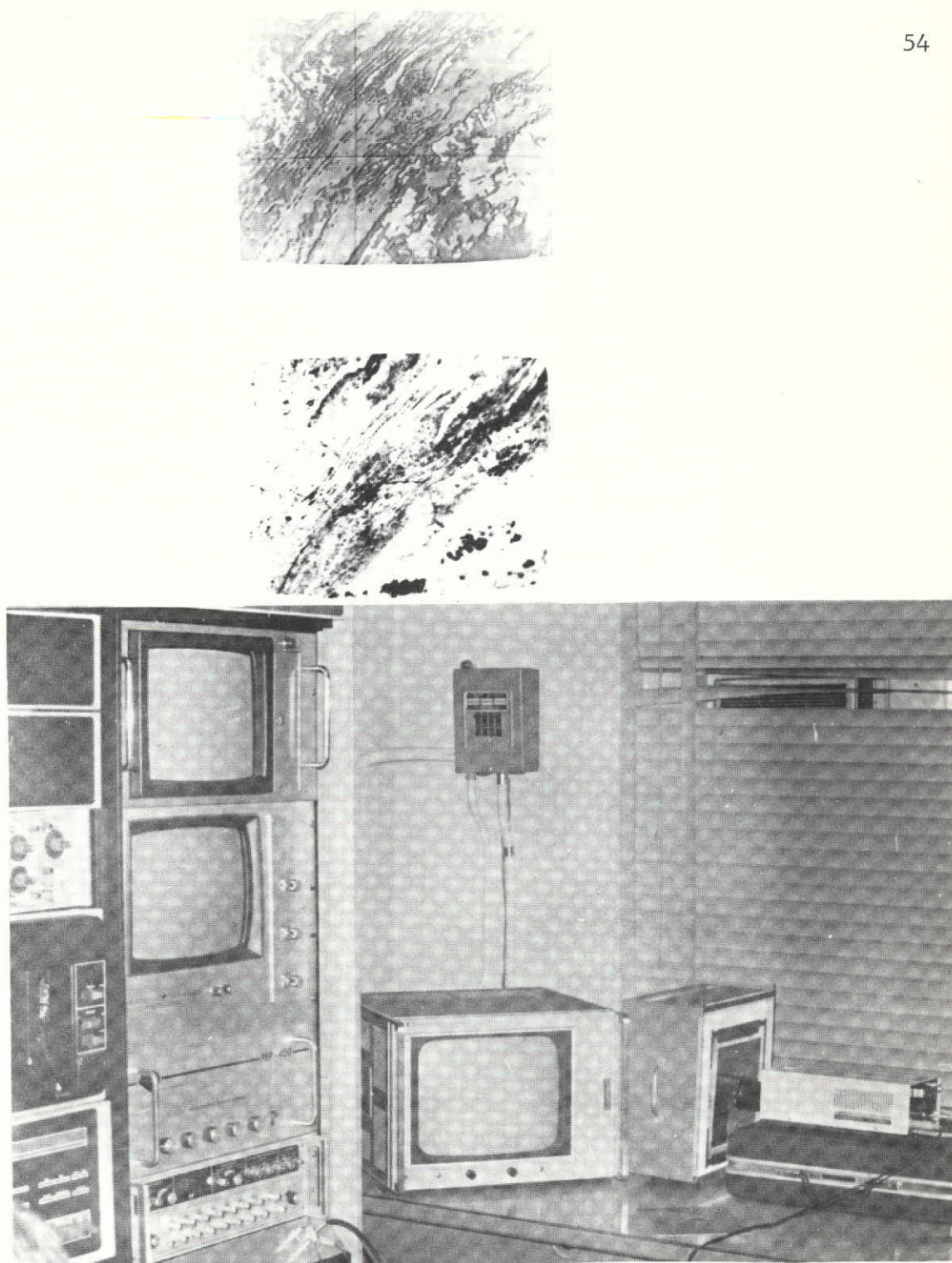


Figure 13. VP-8 Image Analyzer System (below). Note CTV camera at right focused on ERTS transparency, X-Y-Z display at center, and VP-8 analyzer and monitors at left. (above)- Monitor output from VP-8. Upper screen shows density level slices from VP-8. Lower screen shows normal black and white image. Both are negative prints.

signal on a Band 5 ERTS image can be coded in up to 8 colors with a dark or heavy density color such as brown or purple. Another color such as green can be assigned for the next density area for agricultural lands. If a water signature is present it can be assigned above the agriculture category as yellow. For the final density unit, we can assign a bright red or orange for high density settlement and transportation networks. In essence, through the manipulation and assignment of color codes to density levels, we can produce a landuse display based on the above Level I landuse categories.

Can we consider this as a possible working solution to landuse mapping? I believe so but with reserved optimism. First, consider the ways in which we analyze imagery. The human interpreter basically looks at tonal variations in terms of light or dark signatures to interpret black and white ERTS imagery. Tonal variations reflect densities which can be measured, sorted, and displayed by the VP-8 system. Thus, the VP-8 distinguishes between light, gray, or dark toned areas and displays mappable areas to which we assign landuse interpretation. The VP-8 can only reconstitute and sort density levels for us. We must interpret those levels in terms of landuse categories. The interpretation can only be as good as the interpreter. His subjective and objective knowledge of the area enters a bias which the VP-8 cannot override.

The interpreter or VP-8 machine operator selects the color assignments for different densities and also determines, in part, the spatial distribution of density levels. He can combine density levels into a common color unit and thus obliterate detailed information. Conversely, the interpreter can display up to 8 density color slices and combinations with highly

detailed definition. It is this kind of subjectivity in the choice of density combinations which alarms some investigators.

No single interpreter, interpretation system, or for that matter data gathering device, or sensor can possibly meet the needs of every investigation. The VP-8 must be used with caution with the understanding that it produces color coded densities which the interpreter must choose to display.

Besides landuse mapping from the VP-8, we have experimented with its use in detecting high density settlement such as central business district areas, shopping center complexes, and suburban subdivisions. High density settlement features reflect from ERTS imagery in bright returns. By selecting only the brightest signatures for an urban scene, from the VP-8 choice of densities, we can present and identify the areas of high density settlement. Caution, again, must be taken in the interpreter's choice of bright signal returns because airport runways return the same signals as high density settlement.

2.50 SUMMARY AND CONCLUSIONS

Techniques of data collection and analysis used within the investigation included: (1) multi-stage sampling procedures, (2) photographic enhancement techniques, (3) microdensity and computer mapping techniques, and (4) electronic image enhancement and analysis techniques. Of these, the multi-stage sampling procedures and the photographic techniques provided more direct utilization to the goals of the project. Both techniques-systems generated effective data collection and basic analysis to the problem of landscape change detection and monitoring. The multi-stage

sampling procedures produced a selected variety of image scales which could be cross-compared, contrasted, and analyzed for change detection and analysis. Photographic techniques produced enhanced imagery which enabled us to distinguish between landuse and landscape categories such as forest, water, agricultural/cultural, urban, highways, and strip mines.

Disappointing to the present investigator's results, but potentially useful are the techniques of microdensitometry-computer mapping and the image analyzer system. Although our utilizations of these techniques were minimal because of mechanical breakdowns and delays in receipt of imagery and equipment, we are confident that these techniques could benefit future experiments and investigations in landscape change detection and monitoring. The computer mapping portion of these techniques holds the most promise for change detection and mensuration. The image analyzer system provides a promising capability in area measurements of selected densities. Hopefully such densities can be eventually and exclusively identified with single landuse categories. Because the computer and image analyzer systems depend wholly on densities, the difficulty of separating densities of like properties such as clouds from strip mines and certain bright reflecting water surfaces from high density urban areas for areal measurement remain beyond the scope of the present investigation.

PART III

THE APPLICATIONS OF ERTS-I IMAGERY TO THE LANDSCAPE CHANGE ANALYSIS OF SELECTED PHOTOMORPHIC REGIONS

The following sections, 3 through 8, report on the primary applications of ERTS-I imagery for the analysis of landscape change. Through these efforts and results, the utility of ERTS as a system for detecting and monitoring landscape change is illustrated. Additionally, the results further illustrate the varying scales of data and their presentation through the use of ERTS imagery. For instance in section three on strip mining, the mapped data base is 1:120,000 to which ERTS data are modified to fit. In section 4, 14 ERTS images are mosaiced to cover the agricultural regions of Tennessee, Kentucky, and parts of Alabama and Mississippi. Section 5 on Tennessee's forest cover is also the result of a mosaic of 14 ERTS images. Section 6 on urban-suburban growth detection is based on a 1:120,000 scale modification. Finally, section 7 (Short Lived Phenomenae) is based on the normal 1:1 million scale of the 9 x 9 ERTS imagery except for the mosaics of the Mississippi River floods of 1973.

3.0 LANDSCAPE CHANGE ANALYSIS - STRIP MINES

3.1 INTRODUCTION

The applications of ERTS-I imagery to the detection and monitoring of strip mining landscape change are positive, reliable, and capable of becoming operational. The strip mine landscapes on the Cumberland Plateau in Tennessee are excellent examples of dynamic landscape modification representing a variety of states of change: (1) recently cleared/deforested, (2) actually stripped for coal, (3) current reclamation, and (4) reclaimed. Located in Campbell and Morgan Counties, Tennessee, the Cumberland Plateau Test Site offers all states of strip mining landscape change with the most significant being lands under direct and actual strip mining processes.

3.2 SIGNIFICANT RESULTS

From ERTS imagery and RB-57 high flight imagery, a map depicting strip mining landscape changes has been produced. To facilitate the legibility of the mining changes the map was prepared at a scale of 1:120,000 with the high flight imagery used as the scale and data base and the ERTS imagery enlarged to fit the 1:120,000 map scale.

Figure 14 illustrates the strip mining landscape changes at the test site between the dates of April 18, 1972 and October 15, 1972. The darkest tones on the map represent the strip mines as of April, 1972 mapped from high flight RB-57 imagery. The light gray tones on the map represent additional strip mines and mining expansion as mapped from the October 15th ERTS-I imagery. The ERTS imagery

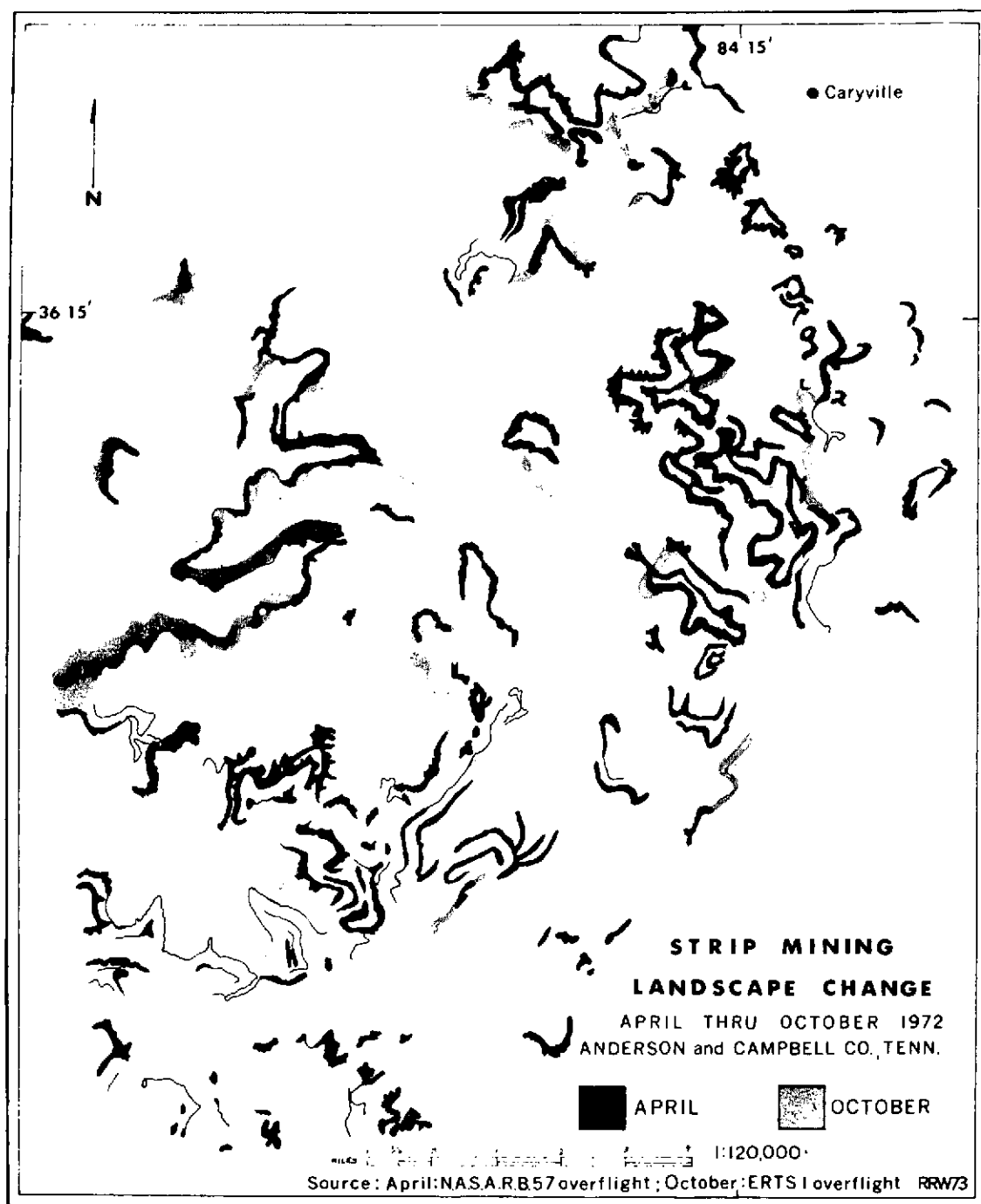


Figure 14. Landscape change created by strip mining at the Cumberland Plateau Test Site. April 18, 1972 - October 15, 1972. NASA/MSR high flight mission 197 image numbers 26-0050 and 26-0063. ERTS-I band 5 id. no. 1084-15431-5.

used to produce this initial strip mine map is a portion of band 5 frame #1084-15431. The modification of the 1:1 million ERTS frame to the 1:120,000 large scale data base presented no problems in registration. The procedure was accomplished by drafting a base map of the strip mines as of April from the high flight imagery. Then with a photographic enlarger, the ERTS image was enlarged to a scale of 1:120,000 and the additional October strip mine signatures were drafted directly onto the base map. Although precise map standard measurements cannot be wholly accomplished from this procedure the overall effect of the map presentation is acceptable. Results from this initial experiment indicate that strip mines can be detected and mapped from ERTS with relative ease and speed and that ERTS offers a potential for monitoring such landscape changes in the eastern United States.

3.3 DETECTION AND IDENTIFICATION OF STRIP MINES ON ERTS IMAGERY

The analysis of ERTS imagery for strip mine detection and monitoring depends on the ability of the interpreter to identify strip mining signatures on the imagery. In Figure 15, a matrix of all ERTS original and enhanced products and the strip mine signatures which can be detected, identified and mapped from ERTS indicates the versatility of ERTS-I imagery.

Strip mines on original ERTS band 5 imagery, appear as light toned, jagged lines on a dark forested background. From a black and white negative enhancement, mining signatures appear as dark, solid lines as illustrated in Figure 17. On band 7 from the ERTS imagery,

DETECTION OF STRIP MINE SIGNATURES FROM ERTS-I IMAGERY

ERTS-I Image Product	Tone/Color	Shape/Pattern	Edge Distinction	Internal Characteristics	Background
Bulk Black & White Band 5 Positive Transparency	<u>White</u> , uniform	jagged lineations	fair to good	None	<u>Dark</u> - forest cover
Black & White Band 5 Negative print	<u>Black</u> , uniform	jagged lineations	excellent	None	<u>White</u> - forest, water
Bulk Black & White Band 7 Positive Transparency	<u>Dark</u> , irregular	dots and smaller lineations	poor to fair	Good for water impoundments only	<u>White</u> , <u>light</u> <u>gray</u> - all land surfaces
Black & White Band 7 Negative print	<u>White</u> , irregular	dots and smaller lineations	poor	Excellent for water surfaces only	<u>Black</u> - for all land surfaces
Bulk Color Composite Positive Transpar- encies (Bands 4, 5, 7)	<u>Yellow</u> , irregular & <u>tan</u>	jagged lineations of newly stripped land - sandstone reflecting	fair to good	Good for distin- guishing water from earth surfaces	<u>Red</u> - forest cover
"	Light & dark <u>blue</u> , irregular	dots and smaller lineations	good	Good for detecting water surfaces within strip mines	<u>Red</u> - forest cover; <u>Yellow</u> - strip mined cleared earth
"	Dark gray and Electric Blue, irregular	lineations and larger dots	good	Best for detecting active and recently stripped mining areas	<u>Red</u> - forest cover; <u>Yellow</u> - cleared earth
Color Composite Negative Print	Dark red maroon, uniform	jagged lineations	excellent	None	Blue, green, cyan - forest cover

Figure 15

strip mines are more difficult to detect because of a convergence of land surface signals on the infrared band 7 imagery. However, water surfaces are sharply detailed on band 7 so that impounded ponds and water catchments which occur following strip mining appear on the imagery. We have been able to detect and measure strip mine ponds as small as 200 feet in width from 9 x 9 black and white transparencies from ERTS.

The bulk color composites of ERTS imagery corroborate the signatures from bands 5 and 7 and add significant combined information. Strip mines appear on the bulk color composites in several signature groups: (1) lineations of light yellow or tan indicating the presence of cleared earth and sandstone surfaces, (2) light or dark blue dots indicating impounded water in surface ponds, and (3) as lineated dark gray and "electric" blue signatures indicating active or recently stripped mines. Similar dark gray and blue signatures can be verified for other strip mining areas such as the Western Kentucky coal fields.

From a negative color print derived from a positive color composite, a uniform, single color/tone signature is produced (see Figure 7). The color negative print, recreates dark etchings of strip mines, much like the black and white negative print of band 5 does and thus internal characteristics are lost from the scene.

In summary, our findings reveal that a multispectral combination of ERTS image products are necessary for a full understanding of the location, distribution, size, shape, and internal characteristics of strip mines as seen from the ERTS perspective alone.

3.4 CHANGE DETECTION OF STRIP MINING

No single remote sensing platform (stage), scale, or sensor can be expected to provide all the information necessary for the analysis of strip mining from a remote perspective. It is imperative that an examination of this form of landscape change begin with a multi-stage multi-scale procedure.

The initial step is to analyze the RB-57 high flight imagery as a data base and identification medium. Strip mines appear on the original color infrared imagery as gray, irregular, jagged lines which follow the contours of the mountains. Unlike local dirt roads, strip mines are usually wider and do not form linkages between each other and other geographical points. Figure 16 is a negative print of the northern portion of the Cumberland Plateau Test Site. The strip mines illustrated here are shown as dark jagged lineations on a white but forested background. Note the extent of cleared, stripped land indicated by the strip mine immediately north and east of the arrow. By comparison in Figure 17 of an ERTS band 5 negative print, we can see not only the configuration of the same strip mine from the previous illustration, but can also detect from this October 15th image an additional section of cleared land marked by the additional dark tones immediately north of the arrow. Of considerable importance is the capability of the negative print to enhance and display the additional strip mines in dark tones. Such enhancements aid in the detection and identification of newly cleared lands and favor the mapping of such features as cleared, stripped, or otherwise deforested land.



Figure 16. Strip mine signatures on a negative print of the Cumberland Plateau Test Site. RB-57 high altitude aircraft mission at 60,000'. Note the absence of strip mines indicated by the arrow as compared with the presence of strip mines for the same location on the ERTS frame in figure 17. 18 April, 1972. Mission 197 site 177, frame 26-0063.



Figure 17. Strip mine signatures on an ERTS-I band 5 negative print. Note the degree of strip mining north of the arrow as compared to figure 16. 12 July, 1973. Id.no. 1354-15431-5.

3.5 GROUND TRUTH INVESTIGATIONS OF STRIP MINES

Within the multi-stage, multi-scale procedure, low altitude aircraft overflights at 7,000' and field work observations have been utilized for the ground truth analysis of strip mines. From the aircraft platform, 70 mm Hasselblad imagery was generated in normal color Ektachrome and Color Infrared film types. In Figure 18, the imagery has been reprinted into negative prints which illustrate three stages of strip mine development. Image 1 illustrates the initial landscape change activity in strip mining — i.e. forest clearance. The dark lineation is newly deforested swath which has been prepared in anticipation of continued strip mining. Image 2 displays the surface contrasts between a swath of recently deforested ground and a swath of land being stripped for coal at the cutting edge of the strip mine operation. Image 3 displays the same mine as in image 2 but with more coverage of the rough gouged surface, road tracks, and deep pits where an auger is being used. Image 4 illustrates the relative revegetation — natural reclamation of older strip mining scars. Although the mines in image 4 are being reclaimed by natural overgrowth, they are approximately 12 to 15 years old and are being reclaimed at a slow rate. The characteristic signatures from the old mines are their narrow width of 30' to 80' and the natural vegetation of pines, scrub oak, and undifferentiated brush which is reclaiming them. Because of these subtle signatures, older strip mines and their reclamation cannot be detected on ERTS imagery. It may be possible to detect the positive reclamation of the newer wider (300 to 2,000') strip mines if they are reclaimed with thick stands of

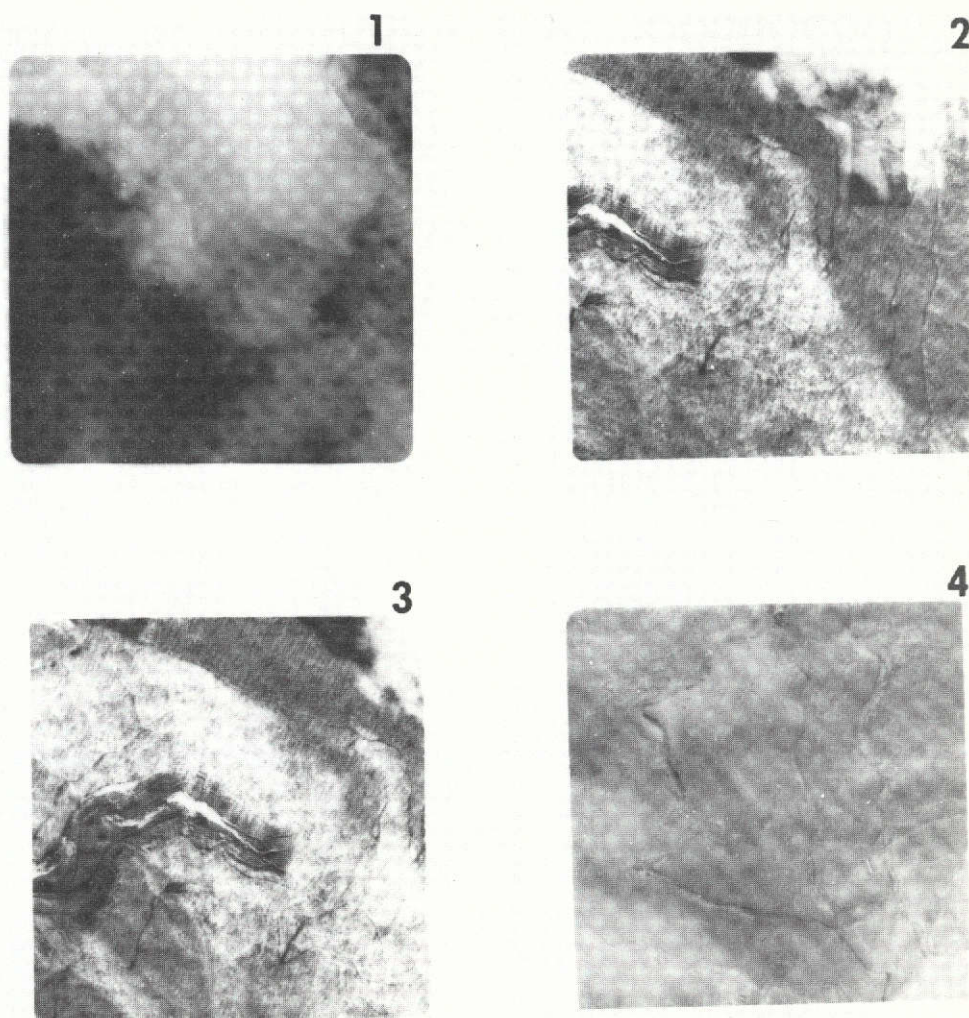


Figure 18. Low altitude aircraft imagery of strip mines on the Cumberland Plateau Test Site. (1) recently cleared; (2) active strip mine at left; (3) active strip mine; (4) old reclaimed mines. All images are negative prints generated from color infrared 70mm transparencies. Altitude: 7000'.

evergreen vegetation and are observed by ERTS during a clear winter overpass. If these conditions of evergreen reclamation and winter observations are not present, then the detection, identification, and mapping of strip mine reclamation from ERTS imagery is not likely to be feasible.

Actual ground truth observations of strip mining yield little additional information other than can be gained from the low altitude aircraft overflights (Figure 19). The strip mines of the Cumberland Plateau are difficult to reach by the slick, narrow, deeply rutted roads, which coal trucks use to haul the coal from the mines. A further difficulty is harassment from some of the mining personnel who view trespassing institutional vehicles (i.e., Federal, state, local government and University cars) as carrying mine inspectors or other regulatory personnel.

Despite these inconveniences our observations reveal that reclamation work in its initial stages can be first assessed only by ground truth work. Fertilizers, and initial grass seeding cannot be detected even from low altitude aircraft. Certainly as the revegetation process begins to flourish, the monitoring of strip mine reclamation becomes possible from the low altitude aircraft platform using color infrared film.

The only other information gained by actual ground truth observations are the verifications of interpretations and analysis of the aircraft and ERTS imagery and the contact with informants in the area.



Figure 19. Ground Truth photograph of a strip mine operation at the Cumberland Plateau Test Site. April, 1973.

3.6 EVALUATION AND POTENTIAL USE OF ERTS IN STRIP MINE DETECTION AND MONITORING

Within any vegetated area in which strip mining is taking place, strip mines and their resultant landscape changes can be detected and monitored from ERTS imagery. The knowledge that strip mines exist in a region is perhaps the initial key to the eventual detection and monitoring of strip mining landscape change. The primary interpretation key, to such detection and monitoring, however, is the target signatures of light tones on dark vegetated backgrounds. It makes little difference whether the vegetation is forest cover, or mixed forest-pasture-cropland combinations as long as the cleared earth signature of the strip mine appears against the vegetated background.

Size and shape signatures verify the existence of strip mines. The appearance of rough textured lineations with no apparent linkages such as occur on the rough topography of the Cumberland Plateau are strip mine signatures. Likewise, the broad irregularly shaped contiguous surfaces of strip mines in the more gentle surfaces of the western Kentucky coal fields display their own signatures for a somewhat different stripped landscape.

For the detection of strip mines of less than 200' wide and revegetated or reclaimed strip mines, ERTS imagery is severely limited. As yet, we have been unable to detect mines with these smaller and more obscure characteristics. ERTS cannot be expected to provide all the necessary data required in strip mine mapping and monitoring. However, it provides enough sufficiently reliable data

from its imagery that I am convinced that ERTS-I and successive ERTS systems have the capability of becoming operational for the identification, monitoring, and mapping of the majority of strip mining landscape changes.

4.0 AGRICULTURAL LANDSCAPE CHANGE

The agricultural landscapes of East and Middle Tennessee are dominated by a chaotic pattern of tiny fields measuring from one-third acre to usually no more than 50 acres in size. With landscape cells as small as these, one would question the feasibility of detecting and monitoring an agricultural landscape from the ERTS perspective of 560 miles altitude.

The analysis of ERTS-I imagery for landscape change within the agricultural category of landuse did not become available until the summer of 1973. The agricultural scene was initially obscured by haze and cloud cover on the August 1972 imagery, almost microscopic on the October imagery, and snow covered on the January and February imagery. However, for April and May, the agricultural landscape emerged as a significantly dynamic surface exhibiting plowing signatures and cleared fields.

4.1 SIGNIFICANT RESULTS

The detection and mapping of plowed fields from ERTS form the basis of significant results. From the April 14, 1973 ERTS-I band 5 imagery of Sand Mountain, Alabama and the Sequatchie Valley of Tennessee, the initial detection and identification of plowed ground signatures began. By negatively printing the band 5 imagery, we enhanced the light toned, cleared plowed earth signatures on the original imagery into dark toned blocks and dots on the negative print (Figure 20). From this initial step of detection and identification we proceeded to mosaic fourteen negative prints of Tennessee, Kentucky, Northern

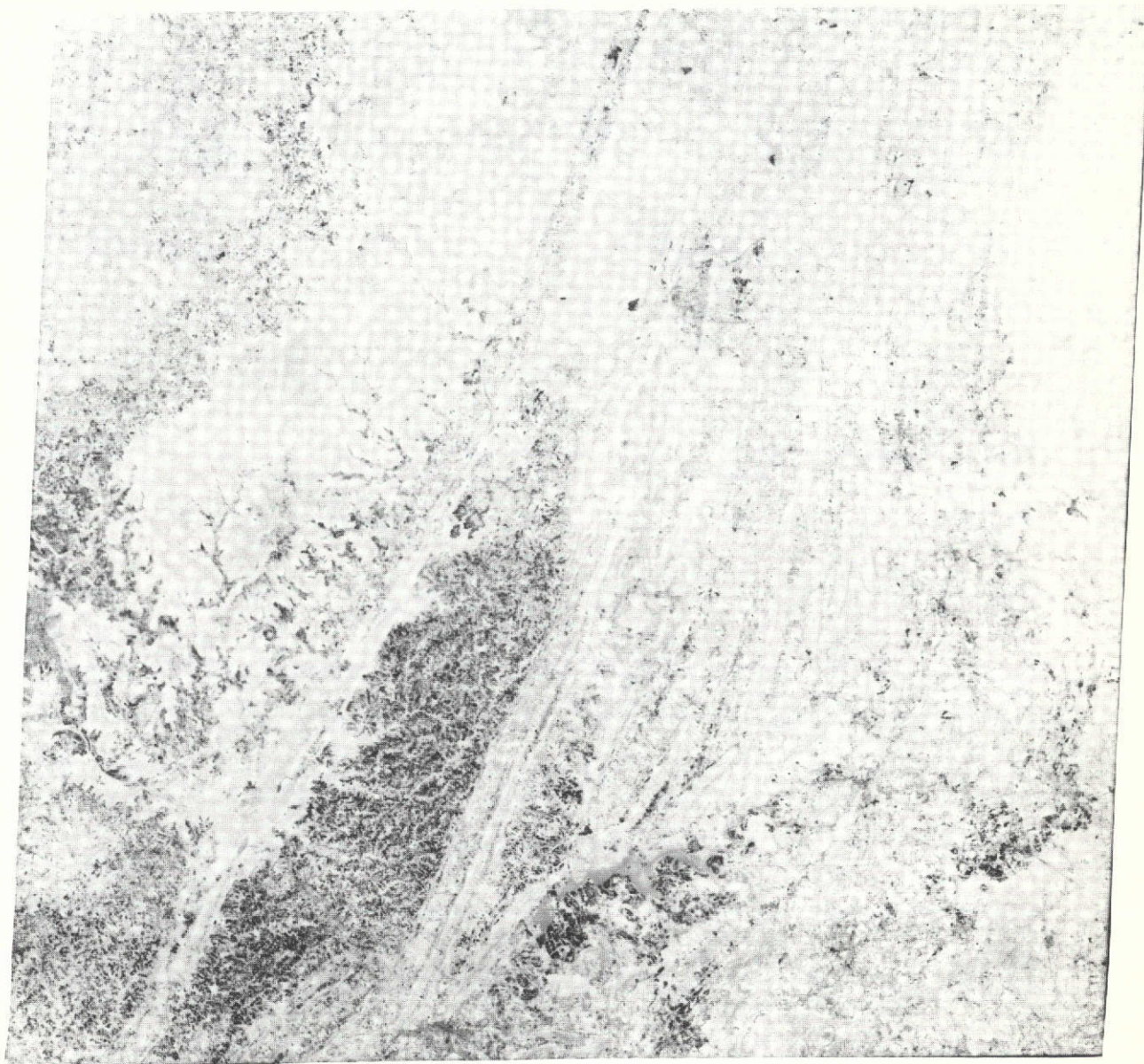


Figure 20. Agricultural plowing signatures (darkest tones) in the Sand Mountain, Alabama area of northeastern Alabama. ERTS-I band 5 negative print. 14 April, 1973. Id.no. 1265-15501-5.

Alabama, and northern Mississippi and to map the areas of dark toned plowed earth signatures for April and May, 1973. The result was the map of agricultural regions in Figure 21.

Finally from the point of view of change detection, the multirate imagery in Figure 22 was mapped and analyzed for landscape change. This substantiated that plowing patterns could be effectively detected and monitored over a temporal period and mapped over a spatial framework.

4.2 INTERPRETATION AND ANALYSIS OF PLOWED EARTH SIGNATURES FROM ERTS-I IMAGERY

The ERTS image in Figure 20 represents an almost ideal condition for the detection of plowing signatures. The dark elongated feature in the southwest corner of the image is Sand Mountain, Alabama, an agricultural region based upon truck garden vegetables and fruit grown on sandstone based soils. The plowed ground signatures are the dots and areas deepest darkest intensity on the negative print.

Perceived as aggregates, the dark tones form a photomorphic region of similar tones. The interpretive value of the photomorphic region is that like tones can be assumed to reflect similar landscape characteristics. In this case the Sand Mountain area forms a most dramatic photomorphic region which exhibits plowed earth signatures — surrogates for potential agricultural crop activity. Southeast of Sand Mountain, additional photomorphic regions of dark tones register for two agricultural regions in the southeast portion of the image near Gadsden, Alabama and Rome, Georgia.

In the western portions of the image beyond Sand Mountain, note the finger-like extensions of agricultural lands reaching into the dissected Cumberland Plateau. West and northwest of the Plateau, the forested area shown in light gray tones, we again see dark signatures indicating the plowed fields of the Highland Rim and Plateau of the Barrens.

Darkest tones on the negative print represent the lightest tones on the original band 5 imagery and both represent land surfaces of brightest reflectance. For this area of the Southeast, such light signatures represent cultural landscapes. For the months of April and May, they represent bare earth. And for rural landscapes they represent cleared, plowed fields.

4.3 MOSAIC MAPPING OF AGRICULTURAL REGIONS

Using the plowed ground signature as a surrogate for agricultural crop activity, 14 ERTS band 5 images were mosaiced in negative print form for the states of Tennessee and Kentucky (Figure 21). Twenty man hours were required to print and mosaic the imagery, and map the regions on the basis of photomorphic signatures (i.e., contiguous areas of dark toned plowing signatures). The speed with which this effort was accomplished reaffirmed our belief that ERTS was an effective system with significant cost benefits. The cost of the ERTS imagery alone would have been \$49. By comparison, RB-57 coverage for the same area would have cost over \$150,000. But more important, the time spent on the project using ERTS imagery only required 20 man hours whereas with RB-57 imagery, the total time required would have been approximately 20 or more man days.

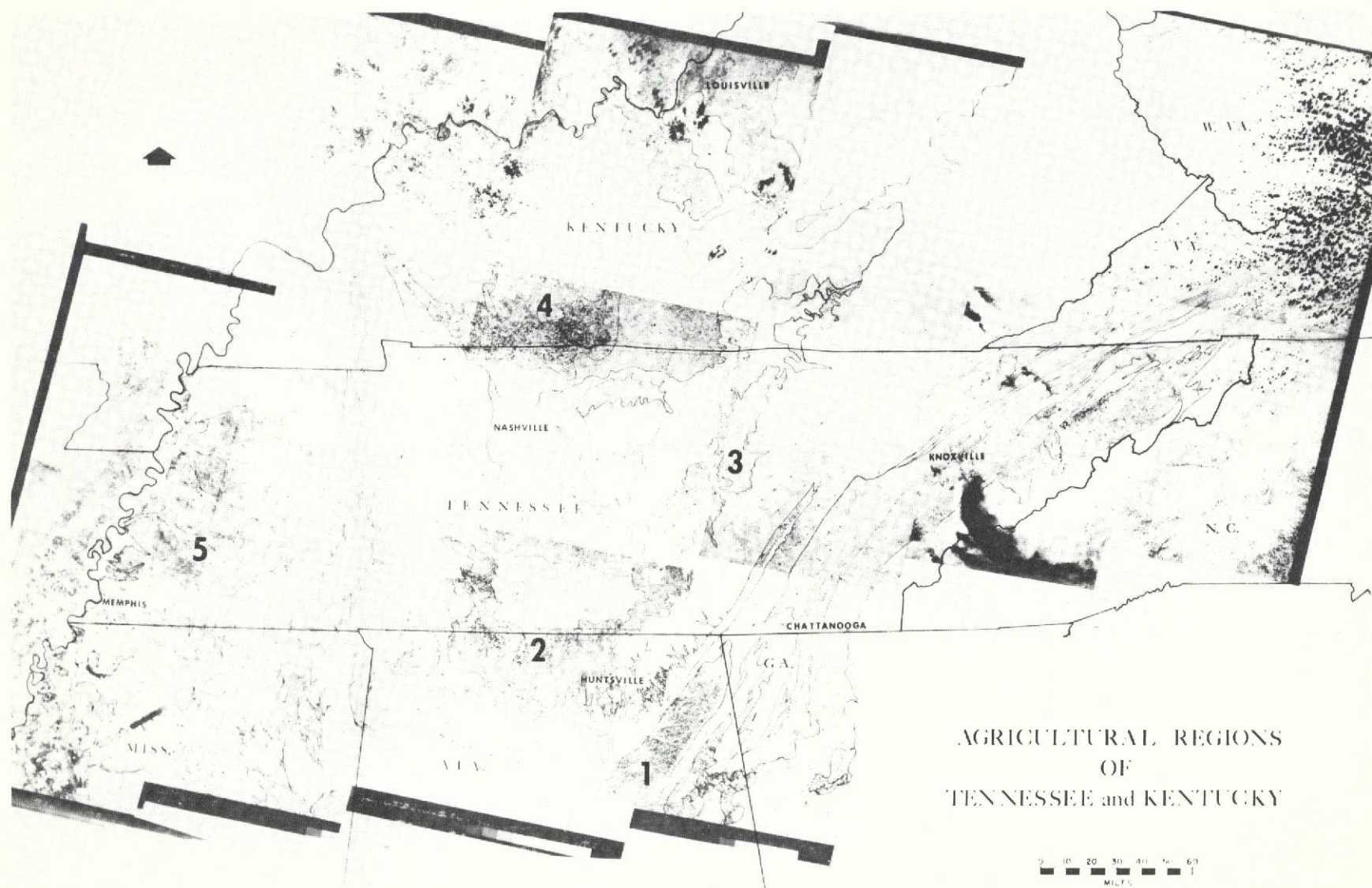


Figure 21. Agricultural regions of Tennessee and Kentucky derived from a mosaic of 14 ERTS-I band 5 negative prints. April-May, 1973.

The interpretative value of any mosaic is that it presents an even larger perspective and region-wide view than its individual components, i.e., the single ERTS frames. We are aware of the ERTS mosaicing efforts of General Electric and commend them on their high quality products. Such mosaicing may be the solution to producing statewide data bases for landuse mapping.

Although the mapped product in Figure 21 is from an uncontrolled mosaic, the visual effect and the interpretive value of the product justify the experiment.

Beginning in the Southeastern corner of the mosaic below Chattanooga and east of Huntsville, one can again see the Sand Mountain agricultural region (1) and lesser regions east of it. Immediately north and west of Huntsville, a large irregularly shaped plowing area denotes the southern portion of the Highland Rim in Tennessee (2). The Rim area is dominated by small farms which for this southern portion signify active plowing signatures.

Northward, the Highland Rim continues in the subregion known as the Plateau of the Barrens (3). Although this area, too, has predominantly small farms, the degree of plowing is somewhat less which indicates a temporal-spatial difference in the timing of plowing practices.

West of region 3 in the vicinity of Nashville are light toned signatures which represent the Nashville Basin, a physiographic region of limestone soils and a rich agricultural heritage. Note the absence of dark plowing signatures. The Nashville Basin today is characterized by a predominance of pasture lands for the grazing of cattle and horses.

Its past was indeed marked by a rich agricultural dominance based on plantation crop agriculture, but today the gentleman's form of agrarian landuse is based on livestock and pasturage for the area.

Region 4 is perhaps the most effective plowing region mapped from ERTS in this mosaic. Its presence on the ERTS mosaic points to the strongest return of the dark toned signatures of plowed fields for any of the photomorphic regions. The Burley tobacco region of southern Kentucky is represented here. Small farms, intensive tobacco cultivation, and a crop calendar of apparent remarkable continuity identify the area as a significant agriculturally active region.

The final region (5), mapped from the ERTS mosaic, is the soybean region of western Tennessee. Alluvial soils, level topography, and a more recent agricultural practice of converting from cotton to soybeans form the basis of this area of plowed fields.

Comparisons between these photomorphic regions as mapped from ERTS and as they appear on the agricultural landuse map modified by James Anderson in the National Atlas reveal a remarkable similarity.⁷ In some ways, the Anderson map (not shown here) is a "ground truth" or control test for the mapping of the burley tobacco and soybean regions. However, the ERTS data were mapped as they appear in Figure 22 before any consultation of the National Atlas was made. Thus regions 4 and 5 shown on the ERTS mosaic are the result of an objective interpretation and mapping effort.

4.4 AGRICULTURAL LANDSCAPE CHANGE DETECTION FROM ERTS

An analysis of ERTS imagery for two successive dates for adjacent areas in south central Tennessee and northern Alabama reveals the capabilities of detecting agricultural landscape change from ERTS imagery alone. Figure 22 illustrates two negative band 5 prints for May 4 and May 21, 1973 for the area. The temporal distance is only one ERTS cycle apart (17 days) yet significant changes can be detected. In the Muscle Shoals-Florence, Alabama area (1) for the two dates, we can see a direct transformation from dark plowed earth signatures for May 4 into a signature of lighter tones for May 21. This represents a change from plowed field conditions to an initial flourishing or greening of the spring crops.

Northward in the Lawrenceburg, Tennessee area (2) of the Highland Rim, the field signatures of light tones for May 4 indicate a dormant state. Plowing conditions have not yet begun. However, by May 21 dark tones appear in the same area indicating a freshly plowed condition.

As indicated by the arrows on the two images, we can thus detect temporal change between the two dates of May 4 and May 21 in terms of plowing signature changes. Area 1 changes from plowed to post-plowed signatures; whereas area 2 changes from pre-plowed to plowed signatures. Furthermore, a brown wave effect can be detected spatially in a south to north movement. Unlike a vegetative brown wave, this brown wave represents the northward migration of plowing practices as a response to a variable crop and plowing calendar.

AGRICULTURAL LANDSCAPE CHANGE

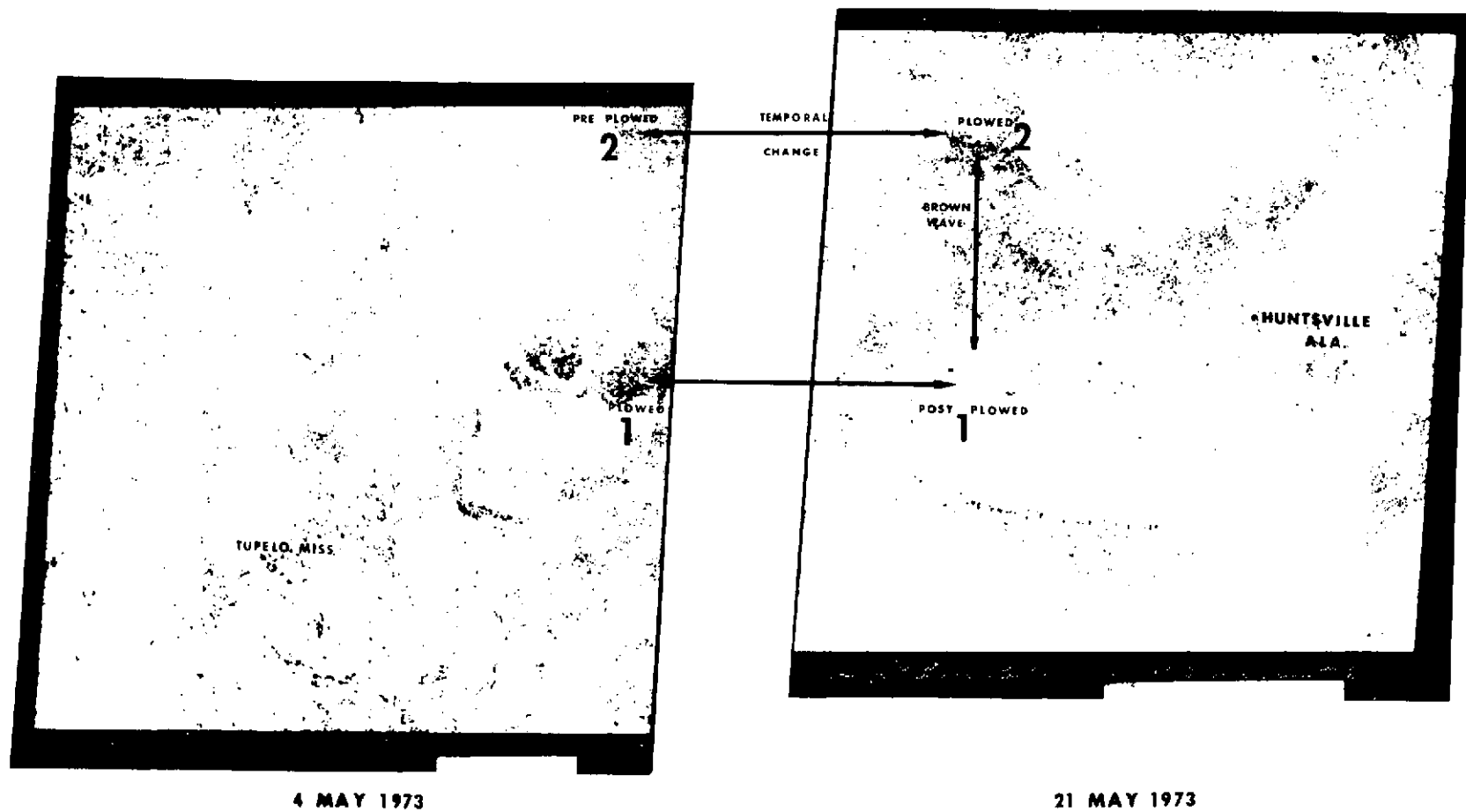


Figure 22. Agricultural landscape change in South Central Tennessee and Northern Alabama. ERTS-I band 5 negative prints. 4 May 1973 Id.no. 1285-16013-5. 21 May 1973 Id.no. 1302-15554-5.

4.5 EVALUATION AND POTENTIAL USE OF ERTS FOR AGRICULTURAL REGIONALIZATION AND CHANGE DETECTION

For an analysis of seasonal vagaries in agricultural landscape conditions, ERTS offers a remarkable combination of temporal and spatial change detection capabilities. The analysis of plowing patterns is perhaps the most significant because, plowed earth signatures are easily detected on ERTS imagery. Furthermore, the presence of plowed earth signatures indicates surrogate information for the immediate future use of lands for crop agriculture. A farming population in this portion of the Southeastern U.S. simply does not plow the earth and leave it in a fallow state. Once plowed, the majority of fields are destined for further agricultural activity, i.e., crop agriculture or improved pasture. Thus ERTS imagery in a black and white negative form provides a remarkable capability for the detection, identification, and mapping of plowed earth signatures as surrogates for active agricultural landscapes.

The ERTS temporal capability of cyclic observations of every 18 days also becomes significant to the detection of changes in agricultural land cover. As the landscape changes from a pre-plowed to a plowed state and on to a post-plowed/crop emergence condition, ERTS imagery can be used to effectively detect and monitor such land cover changes.

Finally, the use of plowing signatures (dark tones) and the change detection capability can be used to regionalize areas of like signatures. Thus, photomorphic regions of agricultural activity can be mapped and changing areas can be monitored through the exclusive use of ERTS imagery.

5.0 THE MAPPING OF FOREST COVER FROM ERTS IMAGERY

Unlike the previous two sections, the forest cover topic is treated thematically and cartographically but minimally in terms of landscape change. As an initial experiment in thematic land cover mapping, the forest cover of Tennessee was chosen as a landscape element to which ERTS data could be applied. Using 14 ERTS band 5 frames, we proceeded to map general forest cover signatures for each image. Then by a mosaicing and scale reduction method, forest signatures were reduced to the map product as shown in Figure 24.

Forest signatures for full foliage periods appear collectively (deciduous and evergreen) on band 5 imagery as dark relatively uniform tones. Conversely, non-forested areas appear in lighter tones of gray to white. Thus the detection and identification as well as mapping of forest signatures is facilitated by these extreme contrasts in signature reflection.

To complete the map in Figure 23 required approximately three hours of mapping time and with the inclusion of the map the total man hours was only six hours. Such time efficiency as this can only lead to a cost benefit ratio of considerable proportions. Compared to ERTS, an RB-57 high flight data base would have required more than \$150,000 worth of imagery and at least 10 or more man days to complete the mapping of Tennessee's forest cover.

One might question the value of mapping generalized forest cover for large areas from ERTS imagery. Despite what is known about our nation's natural resources, as yet an adequate inventory of forest reserves has not been fully accomplished.

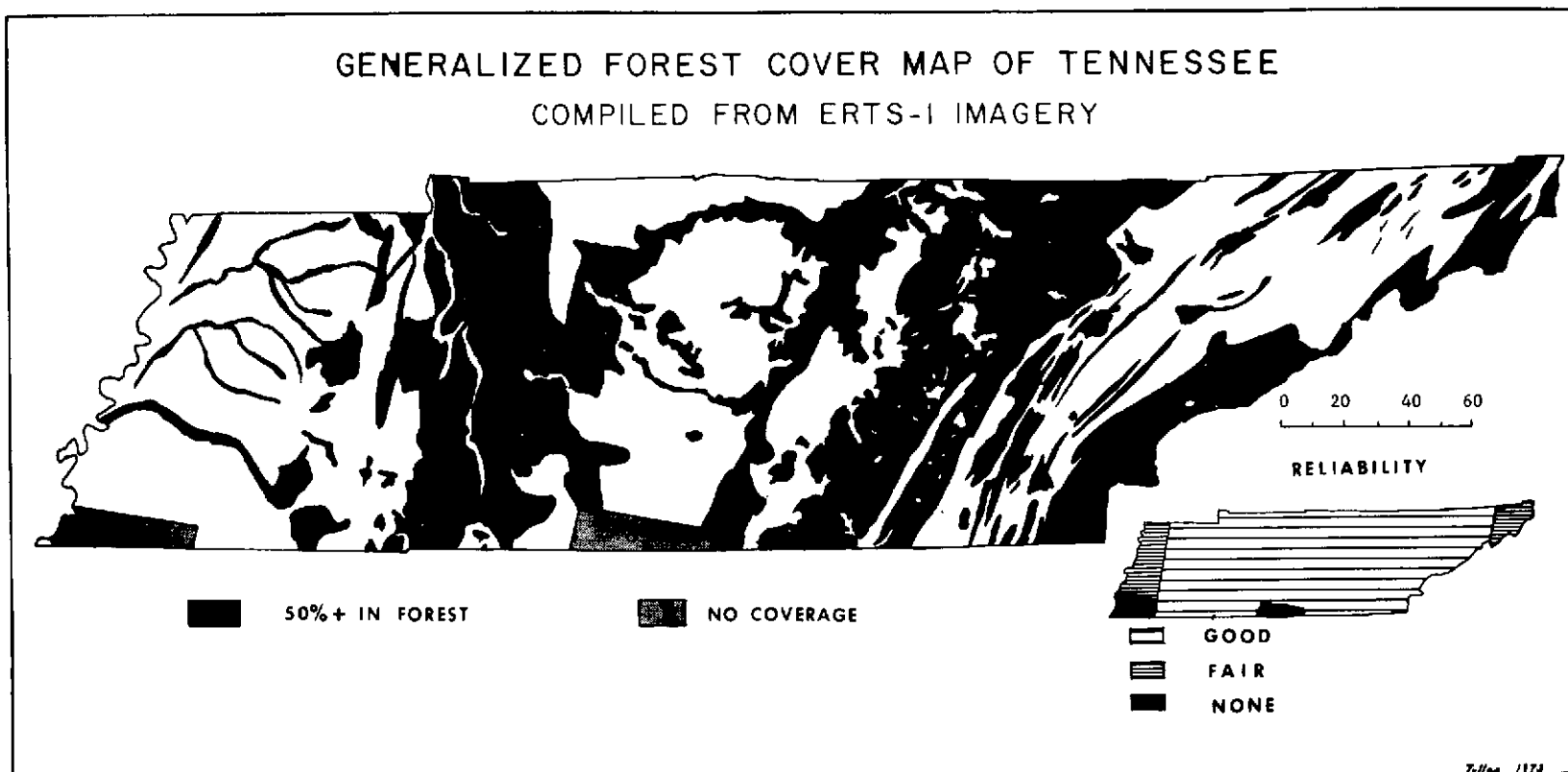


Figure 23. General forest cover of Tennessee derived from 12 ERTS-I band 5 positive transparencies. Various dates between 15 October 1972 and 12 July 1973.

For example, within TVA, a valley-wide inventory of forest cover is needed. TVA has a thorough understanding of sampled forest data on 1/5 acre plots but the region-wide view is missing. Thus, the ERTS perspective offers a quick and easy avenue to solving the problem of mapping and inventorying the forest reserves of the Tennessee Valley Authority region.

5.1 PHENOLOGICAL DETECTION

A most recent preliminary analysis made on February 18, 1974 applies to phenological changes in the forest cover of eastern Tennessee. On an ERTS color composite dated May 18, 1973, a succession of a spring "green wave" phenomenon can be detected. In the higher elevations of the Blue Ridge and Great Smoky Mountains, deciduous species which have not yet leafed out can be detected and mapped. Furthermore, the unleafed deciduous can not only be distinguished from leafed deciduous but more importantly, both can be clearly distinguished from evergreen species of spruce-fir, and the pine. Although time has not permitted a more thorough analysis of this phenomenon, its presence on ERTS imagery provides the forest ecology investigators⁸ a temporal and spatial capability which was unobtainable heretofore.

6.0 URBAN-SUBURBAN CHANGE ANALYSIS

6.1 INTRODUCTION

The analysis of landscape change in or near urban areas has been as perplexing as it has been fruitful. Until the launch of ERTS-I, the efforts of the NASA-ERTS Geography Remote Sensing Project were focused on the urban-suburban growth areas of Knoxville and West Knox County. Low altitude aircraft imagery was generated, high altitude imagery was obtained, and as the initial ERTS imagery began to arrive, we found that urban landscapes diminished in size, scale, and in interpretability from the aircraft to satellite data. From the ERTS perspective the urban scene was amalgamated into almost continuous tones of gray. Certainly, the spider web of roads and routes leading from the city could be detected and mapped; but the cell for cell land units ranging in size from 2-50 acres in stages of significant landscape change were obscured on the original imagery.

The internal characteristics of the city were obscured to the point that landuse categories beyond medium and high density built up could not be easily determined. Contrary to the initial findings of Dr. Robert Simpson at Dartmouth, we were initially unable to distinguish industrial/commercial from residential categories. Our present (1974) internal city analysis continues to experience difficulty in distinguishing the more detailed aspects of urban landuse categories directly and exclusively from ERTS imagery.

6.2 THE DETECTION OF SUBURBAN GROWTH PATTERNS FROM ERTS-I IMAGERY

The multi-stage, multi-scale approach was essential to the analysis of ERTS imagery for changes in the growth areas of Knoxville and West Knox County. Paramount to this effort was the use of RB-57 imagery as a map and data base. Just as with the strip mining analysis, the RB-57 high flight imagery became the comparative data base to which ERTS imagery was adjusted and compared.

Unlike the mapping of strip mines from ERTS and high flight imagery, the suburban change detection and mapping was infinitely more difficult. First, we reprinted both sets of imagery (RB-57 color infrared, and ERTS band 5) into negative prints. Three high flight images of the Knoxville area were then mosaiced and mounted as a data and map base. The negative print of ERTS which had been enlarged to a scale of 1:140,800 was then projected through a vertical projecting system (Map-O-Graph) and adjusted to the 1:120,000 scale of the high flight imagery. At this stage the mapping procedure was begun. A plastic, acetate overlay was placed over the mosaic. Landscape units which appeared on the ERTS as dark tones but which were absent on the high flight imagery were outlined on the acetate overlay (Figure 24).

Several problems resulted from the mapping procedure. Initially the scale adjustments were extremely unwieldy. Not only were they difficult to set but were further difficult to maintain over the entire surface. Aberrations in the lenses of the enlarger and the Map-O-Graph presented distortions in addition to the ones which were present

URBAN - SUBURBAN
LANDSCAPE CHANGE

APRIL 1972 - JULY 1973

DERIVED FROM ERTS-I IMAGERY

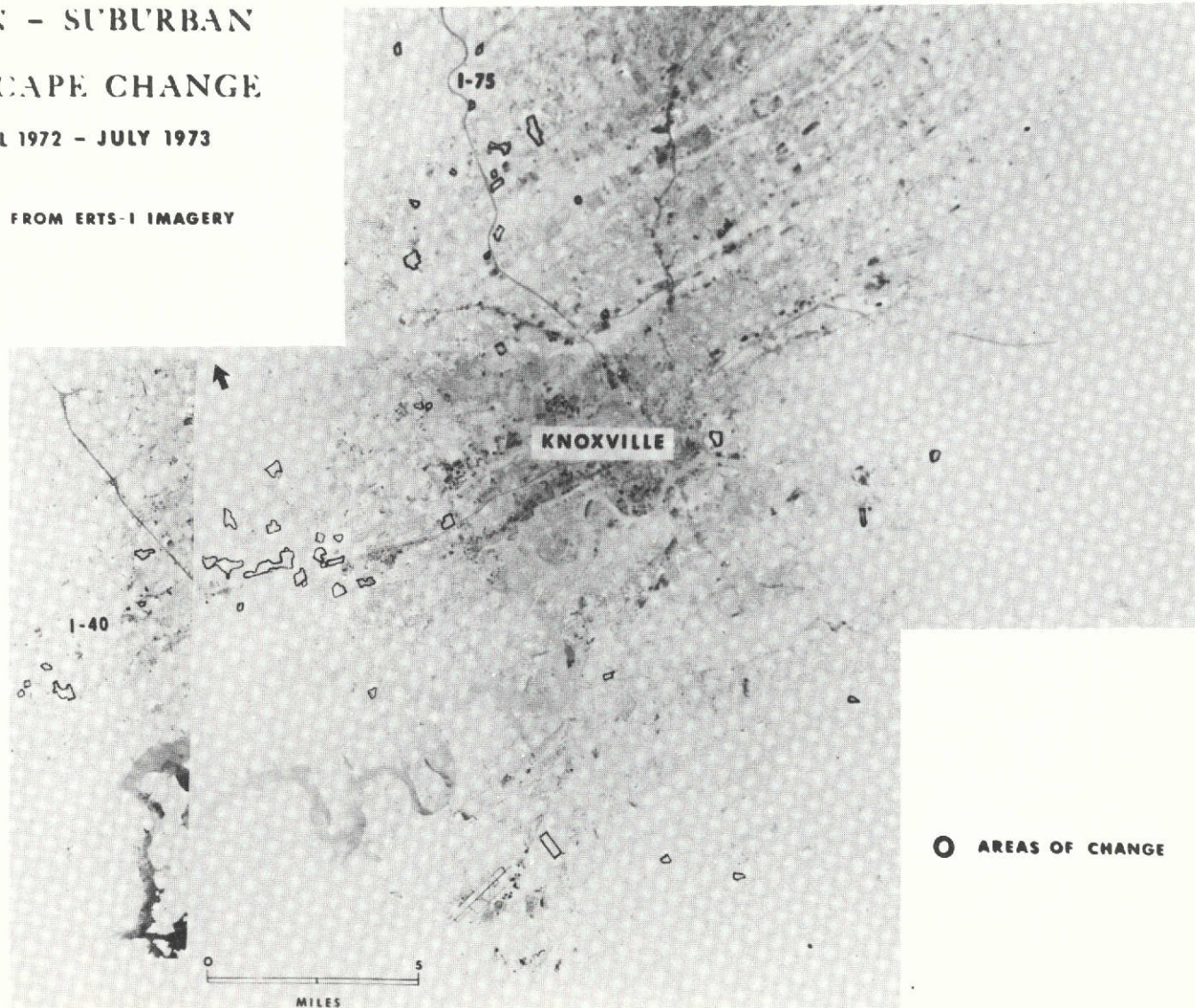


Figure 24. Urban - Suburban landscape change derived from ERTS-I imagery and an RB-57 high flight data base. Aircraft data: 18 April 1972. ERTS data: 12 July 1973. Id.no. 1354-15431-5.

in the prints. Perhaps a more serious problem was the difficulty of identifying the changed areas in terms of their states of change and landuse characteristics.

The information shown in Figure 24 outlines the areas which changed from light tones in April, 1972, into dark tones by July, 1973. The tonal changes identify landscape changes but offer little or no information about the landuse character of the change. The mapped, outlined areas are represented on ERTS as dark toned features on the negative print. On the original imagery they appear as light toned features with very high reflectance characteristics. In either case, it is the characteristic of tone which is the only signature of significance. The most serious problem thus encountered is the answer to the question — What are the varieties of landscape change represented by the dark toned signatures on the negative prints? With the strip mines the identification was simple, dark jagged lineations on a uniform light toned forested background identified as strip mines. But for the urban-suburban scene dark tones of dots, blocks, squares, or nearly any geometric shape except linear can mean anything from bare earth to a full scale and functioning shopping center complete with shoppers!

Despite the identification problems, the question of urban-suburban change detection from ERTS is more positive. I am convinced that changing landscape cells of from 10 acres or more in size can be detected from ERTS imagery but only if the imagery is enlarged and compared to a reliable data source — such as aircraft imagery.

From the analysis of Figure 24 we can detect several patterns of landscape change. Note in the western and northern portions of the map, the clustering of dynamic areas associated with growth along the interstate routes of I-40 and I-75. The changing areas are represented by a variety of states of change and development. Some are simply cleared bare earth surfaces prepared for either current or potential construction. Others are shopping centers, motels, and automobile dealerships. Further, several areas are construction sites for apartments and subdivision development. But in every case, the interpreter cannot identify the state of change or the landuse category from ERTS imagery alone. The other data sources are essential. In the far western portion of the map, the construction of the Oak Ridge-Knoxville highway connector is visible but has not changed (in terms of paving) since the April, 1972 observation. In the center of the image, urban renewal work is taking place near the CBD (Central Business District). To the south of Knoxville, subdivision developments are continuing to emerge but to a lesser degree than the other northern and western growth areas.

Figure 25 illustrates the use of the VP-8 image analyzer for urban landuse and change detection from an ERTS band 5 image. Although change detection aspects have not been developed for the experiment, generalized density patterns reveal areas of highest signal returns which become surrogates for high density settlement. In the upper part of the image, the cursors (crossed lines) identify the CBD area of Knoxville. Radiating outward from the central city are corridors

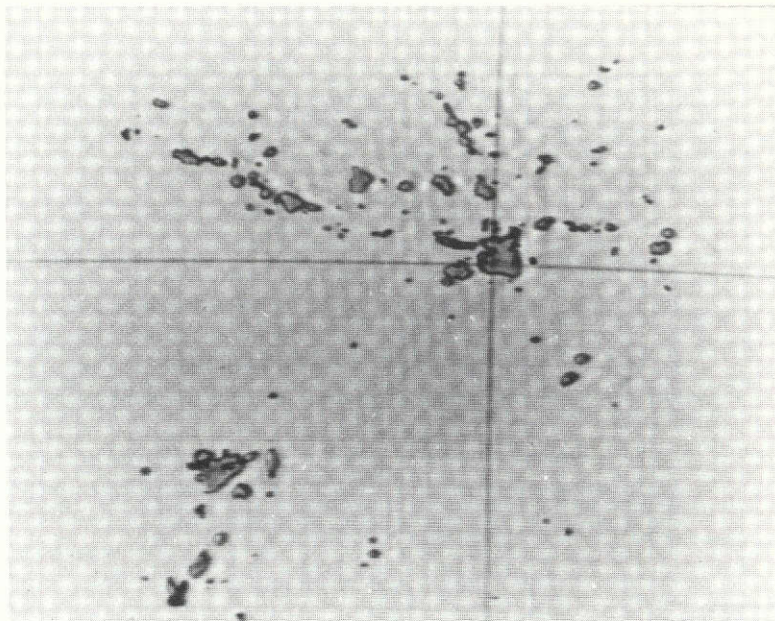


Figure 25. VP-8 image analyzer video output of the Knoxville Test Site from an ERTS-I band 5 positive transparency. Upper monitor enhances areas of high spectral reflectance for the city. Cursors cross at the CBD. The growth areas of West Knoxville are in the northwest quadrant of the image. Lower image has been generated by a normal black and white monitor. Both images are negative prints. 15 October 1972. Id.no. 1084-15431-5.

of strip development and settlement with the longest and most active one extending westward out I-40 west. The large block in the southwest quadrant is the McGee-Tyson Airport. Adjacent to the airport are high density returns indicating Alcoa Aluminum Plants, strip developments (i.e., new car dealerships, mobile home dealers, motels, etc.), and the towns of Alcoa, and Maryville, Tennessee.

Immediately north of the CBD are four large areas of relatively equal size and density oriented in an east-west direction. There are four industrial parks located in an industrial corridor. These same patterns can be seen on the negative print of ERTS band 5 in Figure 26 where landuse areas are labelled on the image. The scale is approximately 1:140,800.

C-2

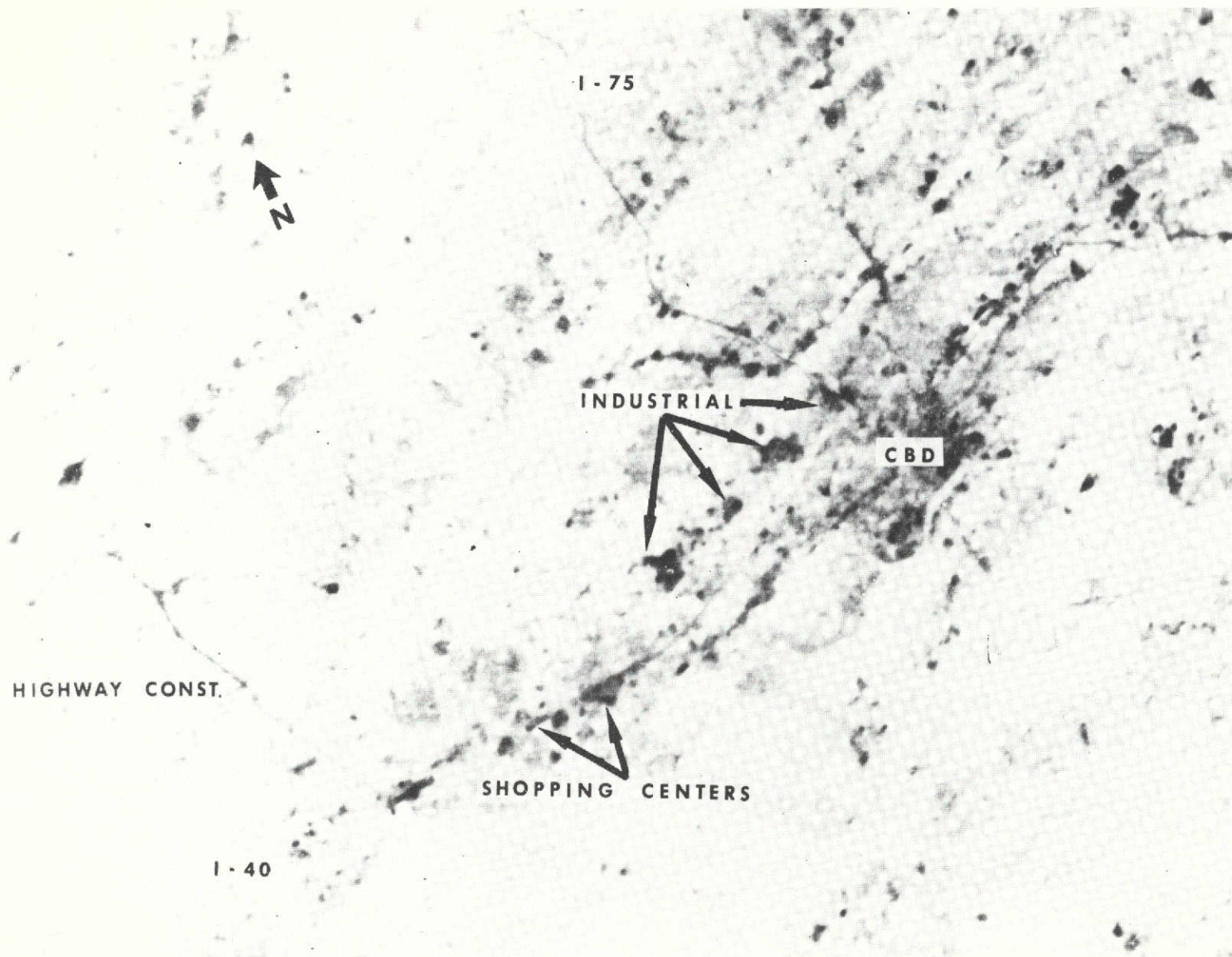


Figure 26. ERTS-I band 5 negative print of the Knoxville Test Site. Scale is approximately 1:140,000. 12 July 1973. Id.no. 1354-15431-5.

7.0 THE ANALYSIS OF ERTS IMAGERY FOR CHANGES IN SHORT LIVED LANDSCAPE PHENOMENAE

7.1 INTRODUCTION

Throughout the course of this investigation, several landscape elements began to show surficial changes which were related to short term conditions of precipitation. Three examples which were analyzed from ERTS data include: (1) the Spring 1973 floods on the Mississippi River between Cairo, Illinois and Memphis, Tennessee; (2) wetted vegetation patterns on the windward slopes of the Great Smoky Mountains; and (3) snow patterns on the southern Appalachians.

7.2 MISSISSIPPI RIVER FLOODS - 1973

Of the short lived phenomenae, the nature of river flooding can leave its most indelible mark on the lives of the people. During the spring of 1973, torrential winter and spring rains caused the Mississippi River and its tributaries to flood to record proportions. Thousands of acres were covered by flood waters and millions of dollars in property losses were suffered. To record the disaster by low altitude aircraft imagery would have been nearly impossible. Even high flight coverage would have been difficult. However, on three frames from ERTS the Mississippi River floodplain from above Cairo, Illinois to as far south as the Arkansas River was covered. Figure 27 illustrates in a change detection and mapping coverage the areas affected by the spring floods. The darkest tones represent

MISSISSIPPI RIVER FLOODING MAY 1973

95

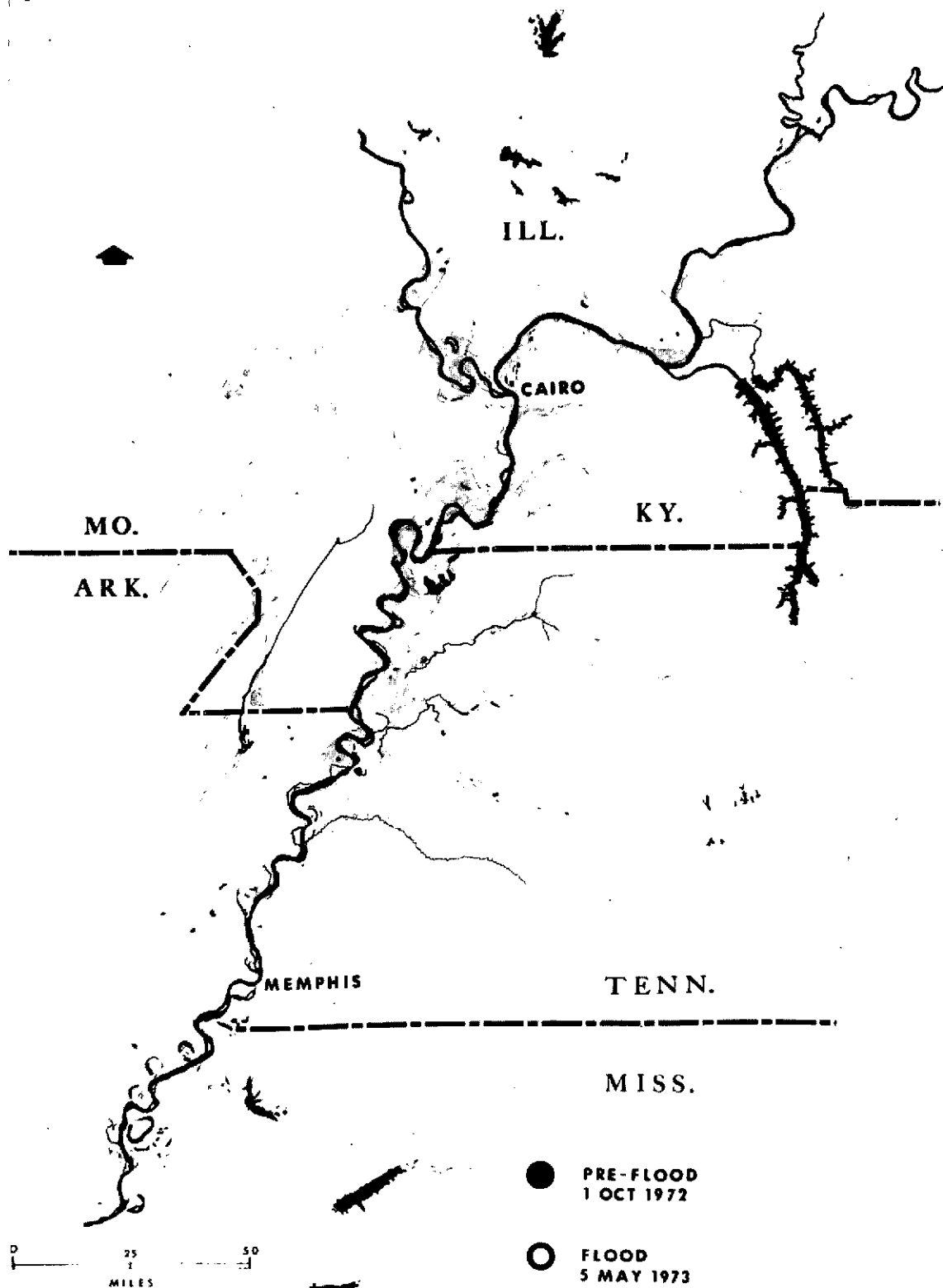


Figure 27. Map of Spring flooding on the Mississippi River between Cairo, Illinois and Memphis, Tennessee. Derived from 3 ERTS-I band 7 transparencies for each of two dates. 1 October 1972 and 5 May 1973.

the river system during normal to low water levels as of October 1, 1972. The lighter tones represent the floods on the Mississippi as of May 5, 1973.

In the upper one third of the map above the Tennessee-Kentucky border, flood waters appear to be localized on the Mississippi River immediately above Cairo and just south of the city. The low lying floodplain areas north of Cairo are restricted in flood to the east of the main river channel on the Illinois side. Conversely, the Ohio River shows fewer signs of major flooding because of high bluffs on both sides of the river. South of Cairo a broad flood area, representing a major flooded section, appears just north of the Kentucky-Tennessee border.

Calculations made of the flooded or water covered areas above Cairo account for more than 400,000 acres (see Procedure below). The closest outside figure to which we can compare these calculations is one of 313,000 acres from a portion of same area reported by Deutsch, Ruggles, Guss, and Yost.⁸ Because the area which we mapped and enumerated is slightly larger than the one measured by Deutsch et al., the differences between the acreages of flood affected land are expected.

The flood affected areas in Tennessee's portion of the Mississippi River show a remarkable concentration of flooded land in the upper half of the area above Memphis. This large inundated area represents the main crest of the Mississippi River flood located in the vicinity of the Tennessee-Arkansas-Missouri juncture with the main thrust

or expanse of serious flood conditions extending northward to southwestern Kentucky. Flooded tributaries such as the Obion, Forked Deer, and Hatchie Rivers in Tennessee are contributing a small proportion of the flooding but the crest is related to flooding conditions which have previously occurred and have collected from upstream on the Missouri, Ohio, and upper Mississippi River systems.

Correlative evidence of the location of the flood crest from Deutsche et al. shows that from hydrographic data the all time high flood crest occurred at St. Louis on April 28, 1973.⁹ The ERTS imagery from which our map was derived is dated May 5 and places the crest at mile 800 or near the Tennessee-Arkansas-Missouri border approximately 65 miles north of Memphis. According to hydrographic data, the crest did not reach Memphis until May 8. The same cresting flood does not reach Vicksburg until May 15. With such data we can thus be assured that the major crest of flooding is represented by the large area of flooding in upper west Tennessee on May 5, 1973. Although comparative data for the acreage in floods between Cairo and Memphis have not been available, our calculations show 967,040 acres of inundation for the area including tributary streams. For the area on the map below Memphis, an additional 300,000 acres can be added. The total area of flood inundation for the entire mapped area (three frames of ERTS imagery) accounts for approximately 1.7 million acres.

Procedure

The map in figure 27 was prepared from 6 frames of ERTS-I 9 x 9 (1:1 million) imagery. Three frames of band 7 for October 1, 1972 were used to prepare the preflood map data which appears in black on the map and three frames of band 7 imagery for May 5 were used to map the corresponding flood conditions shown in gray.

Figure 28 illustrates the six frames for comparison. Although the frames in figure 28 are 70 mm chips, the frames for the original mapping medium were 9 x 9 1:1 million scale contact prints. The map was prepared by tracing the hydrologic conditions shown in black tones onto a stable transparent material. The preflood October 1 data were mapped first followed by the shading of flood data from the May 5 imagery on the same map. For calculating flooded acreage data, a gridded overlay with 1/10" cells was placed over the 1:1 million scale map and cells and portions of cells which covered inundated areas on the map were counted. With each cell calculated at 2.53 square miles the area covered by water equals 731.8 square miles or 468,352 acres. These are not firm figures as some degree of error is expected in the estimation of areas for partially covered grid cells. Furthermore, such calculations were made from the drafted map after flood data were traced from ERTS imagery to the map. Each step in data transference thus provided another element of error.

PRE-FLOOD
1 Oct. 1972

FLOOD
5 May 1973

99

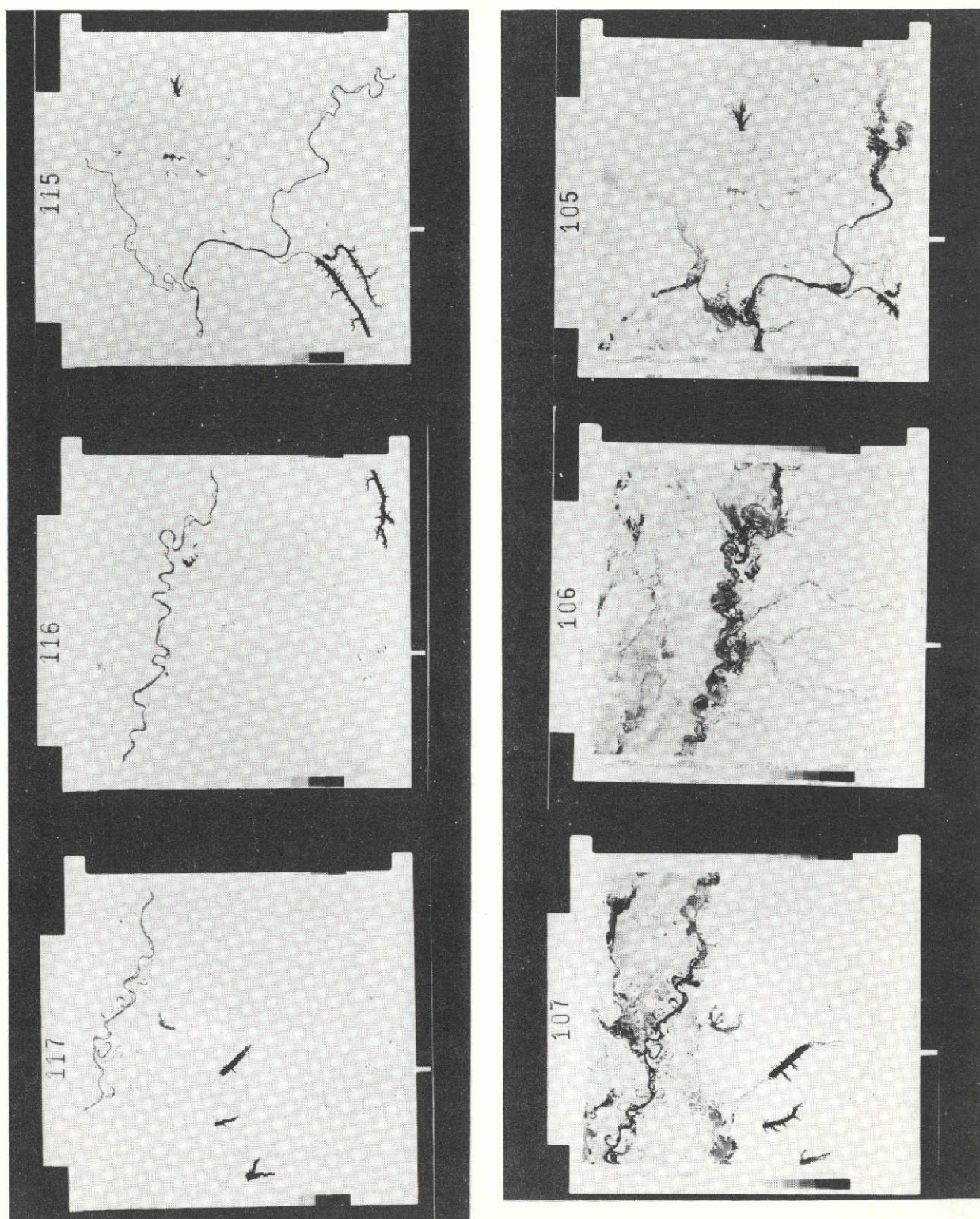


Figure 28. Comparisons between pre-flood conditions and flooded conditions on the Mississippi River between Cairo, Ill. and Memphis, Tenn. ERTS-I band 7 positive prints.

Evaluation

The synoptic and temporal capabilities of ERTS-I have served us well in this endeavor of flood mapping. Without the temporal coverage, the preflood and flood parameters could not have been determined. But more important is the speed with which the three frame sequence was made. ERTS required 1 minute 17 seconds to record this short-lived phenomenon of regional flooding. Water fluctuations, the filling of lowlands, the draining of others, would require only a few hours or days at most to change the complexion of the flood. But ERTS gives us a "stop watch" like static view of the scene. Had high altitude aircraft been used, many flying hours would have been required to cover the Mississippi floodplain and its flood. Small detailed views would have been obtained but the aircraft coverage would have lacked a synoptic overview of the areas in crest flood conditions, the areas which had just experienced the passage of the crest, and the predictive coverage of unfortunate areas about to receive the flood crest. The Mississippi River floods were a regional problem, a short-lived phenomenon, and ERTS provided a quick-look synoptic perspective necessary to analyze and evaluate the damaged region.

Cost benefits are always difficult to assess but had we wished to cover the entire Mississippi flood region to the Gulf of Mexico, only seven frames would have been required at a cost of \$1.75 per print from the USGS-EROS Data Center at Sioux Falls, S.D. High altitude aircraft imagery from the Data Center would have cost

\$3000+ and would not have covered the same expanse of coverage which would have been provided by \$12.25 worth of ERTS imagery.

7.3 PRECIPITATION PATTERNS ON THE GREAT SMOKY MOUNTAINS, TENNESSEE/ NORTH CAROLINA

Additional applications toward earth resources management problems involved the quick-look analyses of precipitation patterns on the Great Smoky Mountains and Blue Ridge areas of the Southern Appalachians.

The Great Smoky Mountains represent a region of cyclic, seasonal change for which natural and not man-made causes predominate. Figure 29, a band 7 positive print, shows a large dark toned area on the western, windward slopes of the Smokies. The day preceding this ERTS observation, a frontal storm system deposited 2"-3" of rainfall on the windward slopes. By comparison, Knoxville located downslope in the Valley received 1.12" of rainfall. The wetted vegetated surface shown here in dark tones was sufficiently wet to register in tones similar to the surrounding streams and TVA reservoirs to the north and west. The satellite monitoring of a watershed such as this has application toward water resources, flood prediction, and a host of other water management problems.

Snow cover on the Southern Appalachians of North Carolina and Tennessee is not an uncommon occurrence. However, infrequent snows of undetermined depth and areal coverage strike the region every winter. Snow cover rarely remains long enough for multiple snows

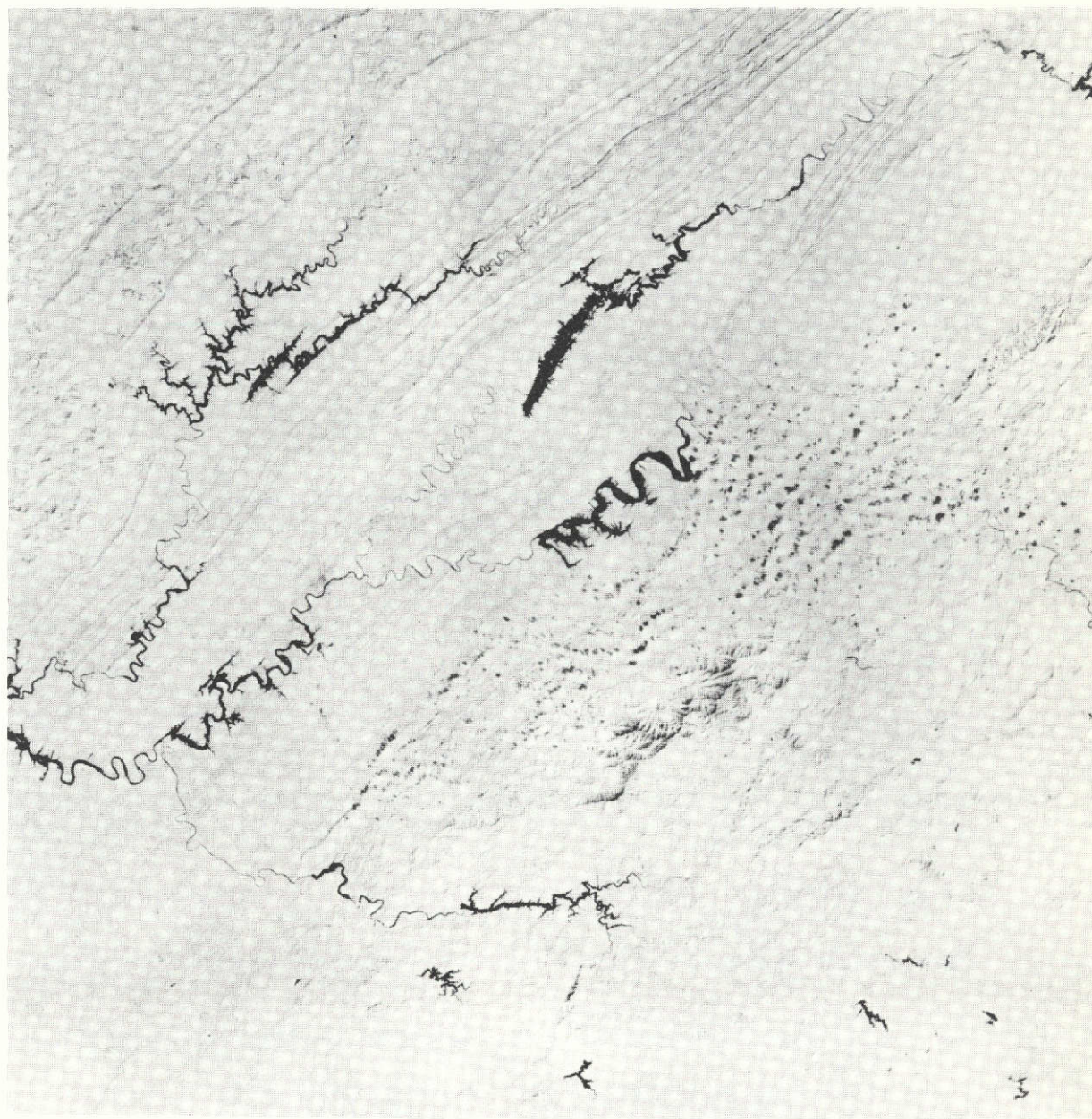


Figure 29. Wetted Spruce-Fir vegetation on the windward slopes of the Great Smoky Mountains, Tennessee-North Carolina. ERTS-I band 7 positive print. 15 October 1972. Id. no. 1084-15431-7.

to accumulate so that each snow is usually a distinct and separate occurrence. Although not every snow can be expected to be recorded by ERTS on its 18 day cycle, the use of ERTS as a weather monitoring device does have application. For the winter of 1972-1973, four snow cover periods were recorded by ERTS observations on the Southern Appalachians. Figure 30 illustrates the pattern of snow cover in the area for February 17, 1973. The pattern illustrates the west to east progression of the frontal system which precipitated the snow. The eastern front of the Blue Ridge Mountains and upper Piedmont area in North Carolina show a striking absence of snow as indicated by the areas of dark tones. The remaining areas of white tones adequately show the regional distribution of snow cover for the photo region.

Evaluation

ERTS continues to provide operational capability in monitoring landscape change even in the category of short lived phenomena. ERTS-I band 7 imagery is significantly effective in detecting and monitoring surface hydrologic features whether they are permanent, lakes or streams, flooded areas, or temporarily moisture covered vegetation surfaces. ERTS-I is a timely system for monitoring watersheds such as in the Southern Appalachians where heavy rainfall areas can be monitored and where snow cover patterns can be mapped. The utility of such monitoring has application to storm caused landslides and local floods as well as applications to recreational landuse planning for winter sports where data for snow cover patterns and north facing snow covered slopes are essential.

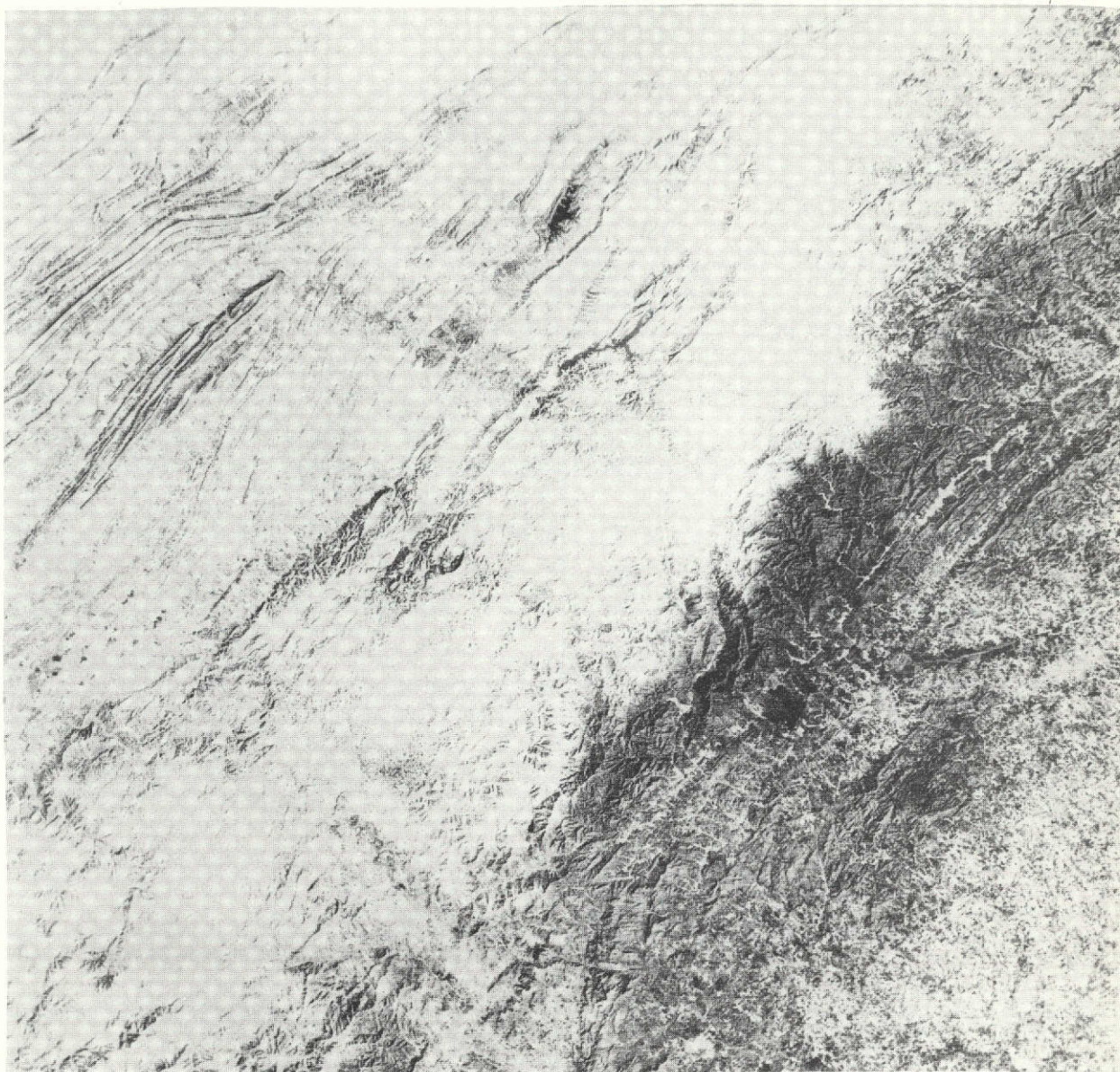


Figure 30. Snow cover on the Southern Appalachians, Tennessee-North Carolina. ERTS-I band 7 positive print.
17 February 1973. Id.no. 1209-15380-7

8.0 SUMMARY AND CONCLUSIONS

ERTS-I has proven to be an effective earth-orbiting monitor of landscape change. Its regional coverage for large areal monitoring has been effective for the detection and mapping of agricultural plowing regions, for general forest cover mapping, for flood mapping, and for short-lived precipitation mapping patterns. We have been *strip mine mapping* indeed pleased with this capability and congratulate NASA for its choice of altitude for the satellite to provide such regional coverage.

Paramount to the entire study has been the temporal coverage provided by ERTS. Without the cyclic coverage on an 18 day basis, temporal coverage would have been inadequate for the detection and mapping of strip mining landscape change, the analysis of agricultural landscape change based on plowing patterns, the analysis of urban-suburban growth changes, and the mapping of the Mississippi River floods.

Cost benefits from ERTS are unquestionably superior to aircraft systems in regard to large regional coverage and cyclic temporal parameters. For the analysis of landscape change in large regions such as statewide areas or even areas of 10,000 square miles, ERTS is of cost benefit consideration. Not only does the cost of imagery favor ERTS but the reduction of man-hours in our project using ERTS have been in the magnitude of 1:10. Thus because of the

cover, or inundated floodplains is estimated at a minimum of one man hour for each man day. We have found that maximum ratios may be estimated as high as one man hour for each 10 man days.

As for the future use of ERTS systems, I have the highest regard and recommendation for the system in monitoring landscape change on a regional scale. Worldwide, operational applications of ERTS to the analysis of earth resources and landscape change are not only possible but should prove to be significant in the future toward the understanding of man's role in changing the face of the earth.

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- ⁶Principal Investigators at the University of Tennessee working on ERTS projects - Dr. John B. Rehder - Geography, Dr. Henry R. DeSelm - Botany-Ecology, Dr. William L. Parks - Plant and Soil Science, Dr. James W. Hilty - Agricultural Biology, Dr. John C. Rennie - Forestry, Dr. John I. Sewell - Agricultural Engineering.
- ⁷Map of "Major Land Uses" adapted from the U.S.D.A. "Major Land Uses of the U.S." by Francis J. Marschner, 1950. Revised by James R. Anderson, 1967, in The National Atlas of the United States of America. United States Department of the Interior, Geological Survey, Washington D.C.: U.S. Government Printing Office, 1970, pp. 158-159.
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